Table 9-7. Computed Threshold D/U Due to IM3 for Equal Paired Signals

	Paired-Signal D/U for $U_{N+K} = U_{N+2K} = U$ (dB)								
	D = -68 dBm			D = D_{MIN} + 3 dB			D = D_{MIN} + 1 dB		
	Worst	2nd Worst	Median	Worst	2nd Worst	Median	Worst	2nd Worst	Median
N-5/N-10	-37.2	-41.7	-42.3	-44.9	-49.3	-50.0	-44.9	-49.4	-50.0
N-4/N-8	-39.1	-40.6	-42.0	-46.7	-48.3	-49.6	-46.8	-48.3	-49.7
N-3/N-6									
N-2/N-4									
N-1/N-2									
N+1/N+2									
N+2/N+4									
N+3/N+6	-33.7	-41.8	-43.7	-41.4	-49.4	-51.4	-41.4	-49.5	-51.5
N+4/N+8	-42.1	-42.4	-46.6	-49.8	-50.1	-54.3	-49.9	-50.2	-54.3
N+5/N+10	-45.0	-46.9	-48.4	-52.7	-54.6	-56.0	-52.7	-54.6	-56.1
N+6/N+12	-47.4	-48.0	-49.4	-55.1	-55.7	-57.1	-55.1	-55.7	-57.1
N+7/N+14									
N+8/N+16	-48.1	-48.7	-51.4	-55.7	-56.3	-59.1	-55.8	-56.4	-59.2

Computation assumes D_{MIN} = -84 dBm

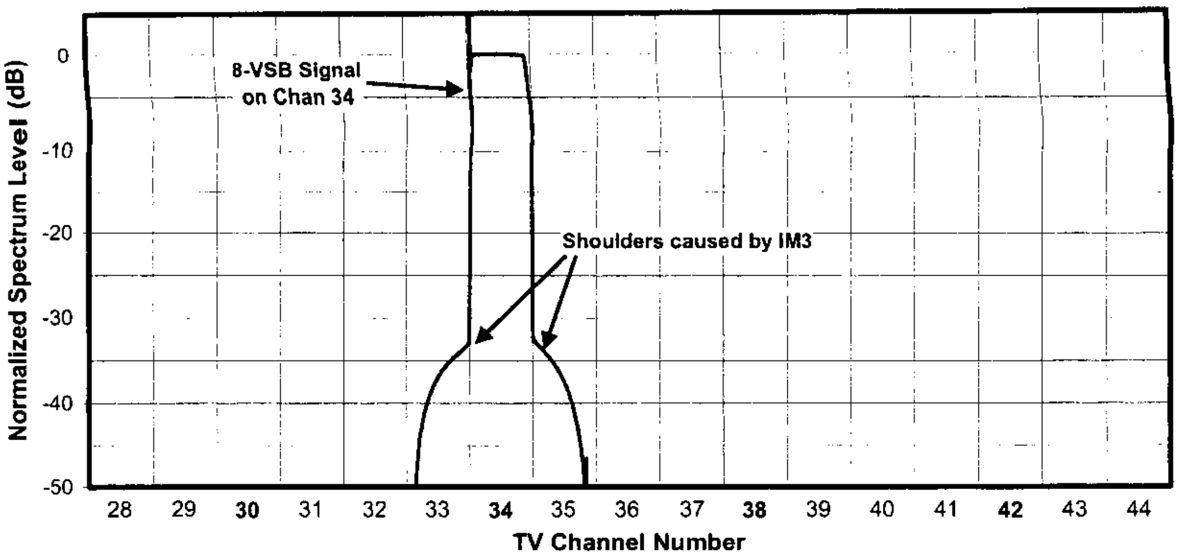
The calculation has been performed for desired signal levels of -68 dBm and D_{MIN} + 3 dB, under the assumption that D_{MIN} = -84 dBm. The results are shown in Tables 9-6 and 9-7.

We note that the absence of data for channel pairs N-3/N-6, N-2/N-4, N+2/N+4 and N+7/N+14 in these tables does not indicate that IM3 was immeasurable on all of the receivers. It means, rather, that conclusions regarding the worst, second-worst, and median values could not be reached from the receivers that were measurable. On the other hand, the absence of data in the tables for the first-adjacent pairs (N-1/N-2 and N+1/N+2) was due to the fact that IM3 effects did not exceed single-channel effects on any of the receivers by a sufficient amount to support measurement of IM3 effects.

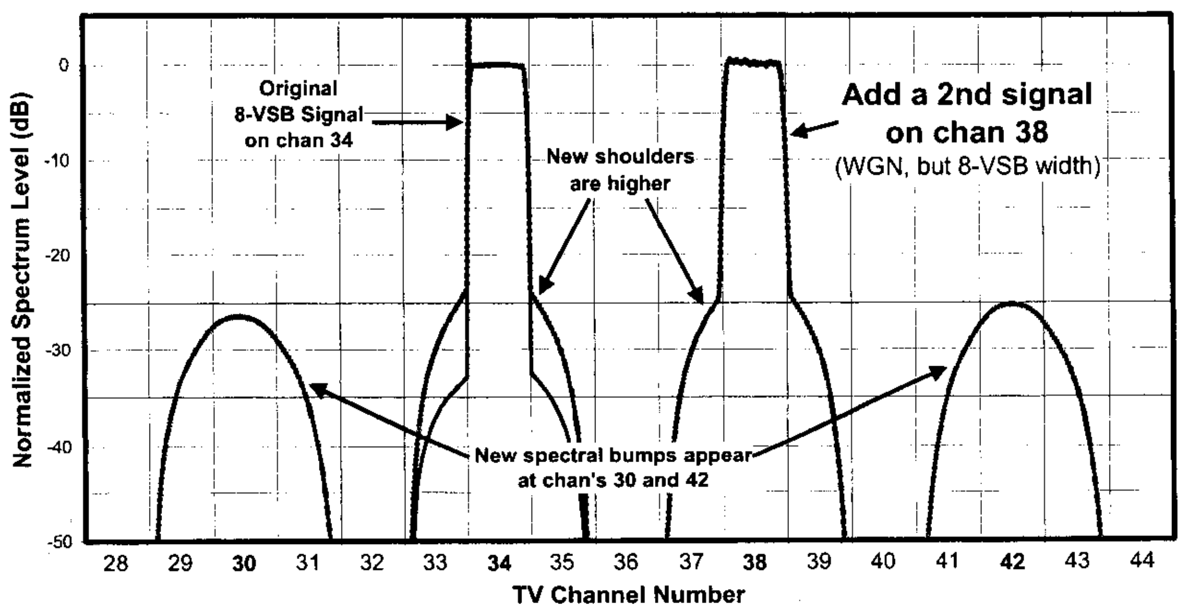
Table 9-6. Computed Threshold U Due to IM3 for Equal Paired Signals

	Threshold U for Paired Signals With $U_{N+K} = U_{N+2K}$ = U (dB)								
	D = -68 dBm			D = D_{MIN} + 3 dB			D = D_{MIN} + 1 dB		
	Worst	2nd Worst	Median	Worst	2nd Worst	Median	Worst	2nd Worst	Median
N-5/N-10	-30.8	-26.3	-25.7	-36.1	-31.7	-31.0	-38.1	-33.6	-33.0
N-4/N-8	-29.0	-27.4	-26.0	-34.3	-32.7	-31.4	-36.2	-34.7	-33.3
N-3/N-6									
N-2/N-4									
N-1/N-2									
N+1/N+2									
N+2/N+4									
N+3/N+6	-34.3	-26.2	-24.3	-39.6	-31.6	-29.6	-41.6	-33.5	-31.5
N+4/N+8	-25.9	-25.6	-21.4	-31.2	-30.9	-26.7	-33.1	-32.8	-28.7
N+5/N+10	-23.0	-21.1	-19.6	-28.3	-26.4	-25.0	-30.3	-28.4	-26.9
N+6/N+12	-20.6	-20.0	-18.6	-25.9	-25.3	-23.9	-27.9	-27.3	-25.9
N+7/N+14									
N+8/N+16	-20.0	-19.3	-16.6	-25.3	-24.7	-21.9	-27.2	-26.6	-23.8

Computation assumes D_{MIN} = -84 dBm

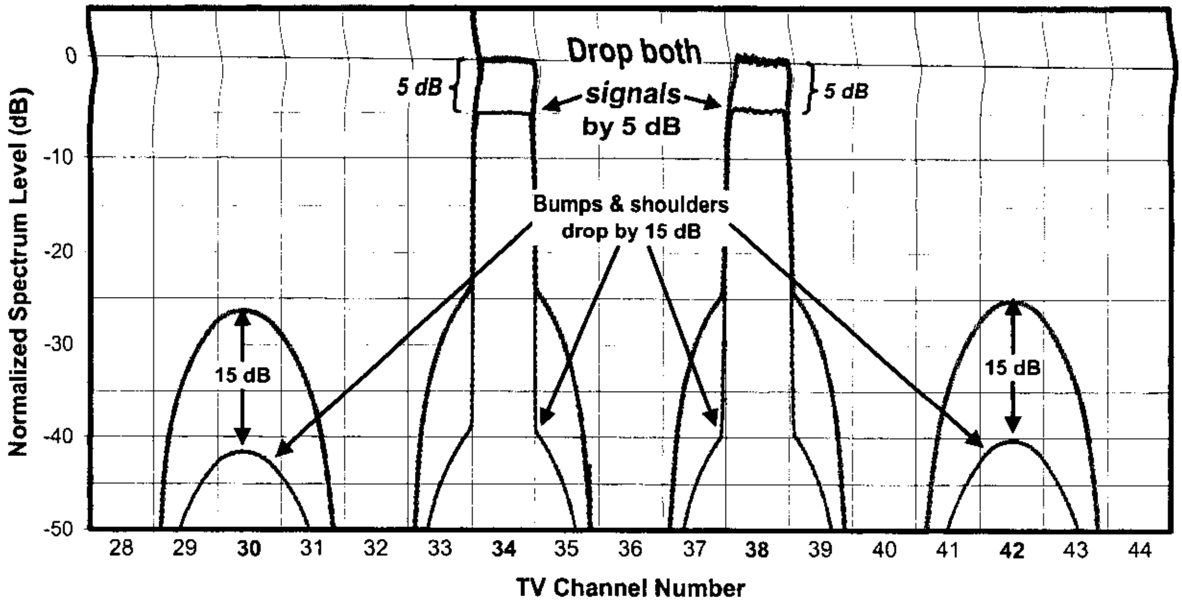


(a) Single 8-VSB Signal

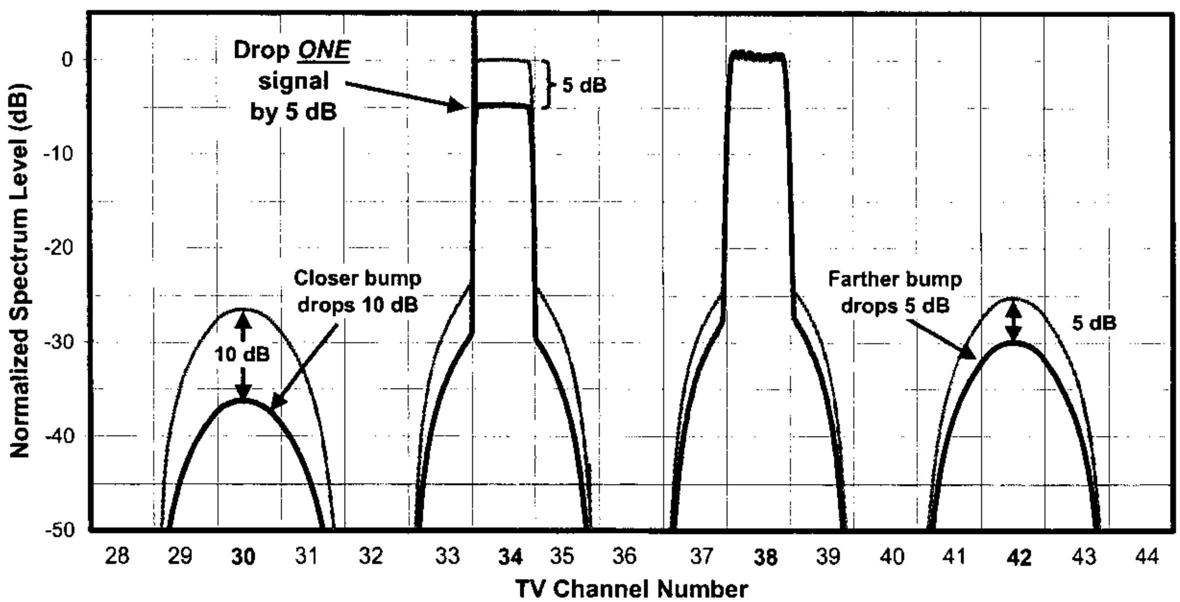


(b) Pair of Equal-Amplitude Signals

Figure 9-1. Third-Order Intermodulation Distortion Spectra of Single and Paired Signals



(a) Effect of Changing Amplitude of Both Signals



(b) Effect of Changing Amplitude of One Signal

Figure 9-2. Third-Order Intermodulation Distortion Spectra of Paired Signals Versus Amplitude

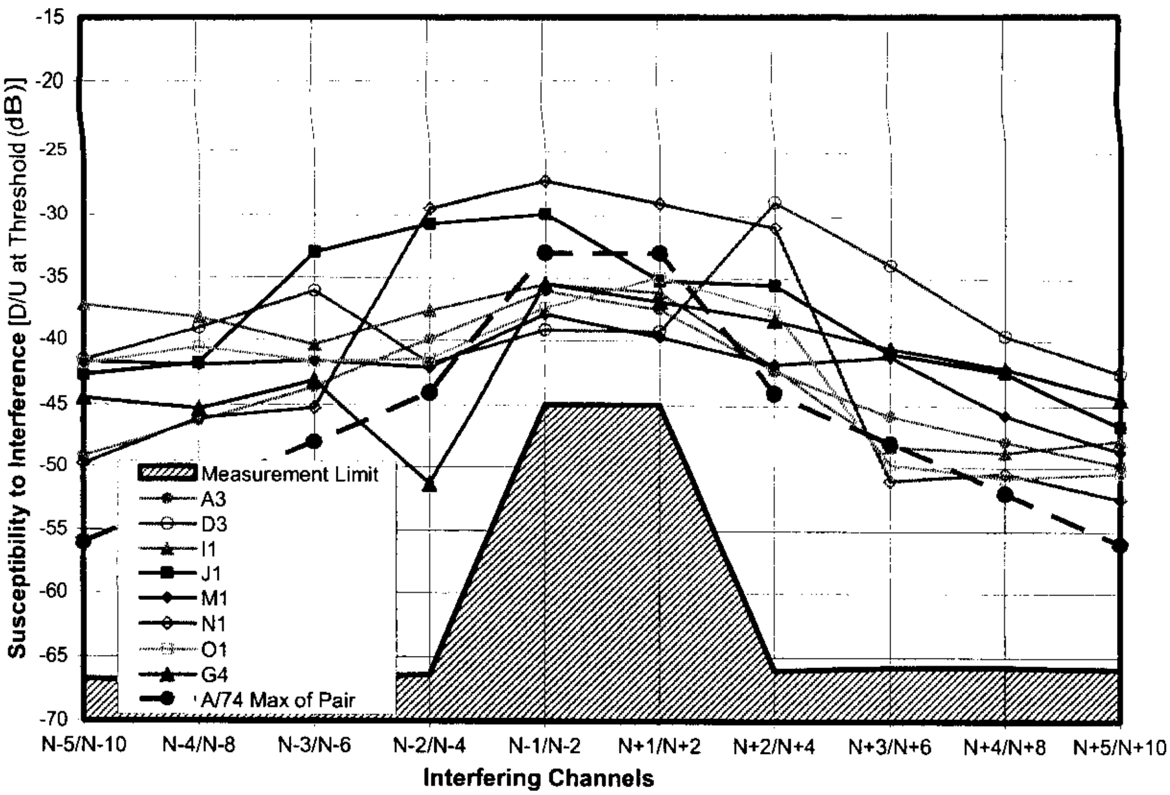


Figure 9-3. Paired-Signal D/U of 8 receivers at D = -68 dBm on Channel 30

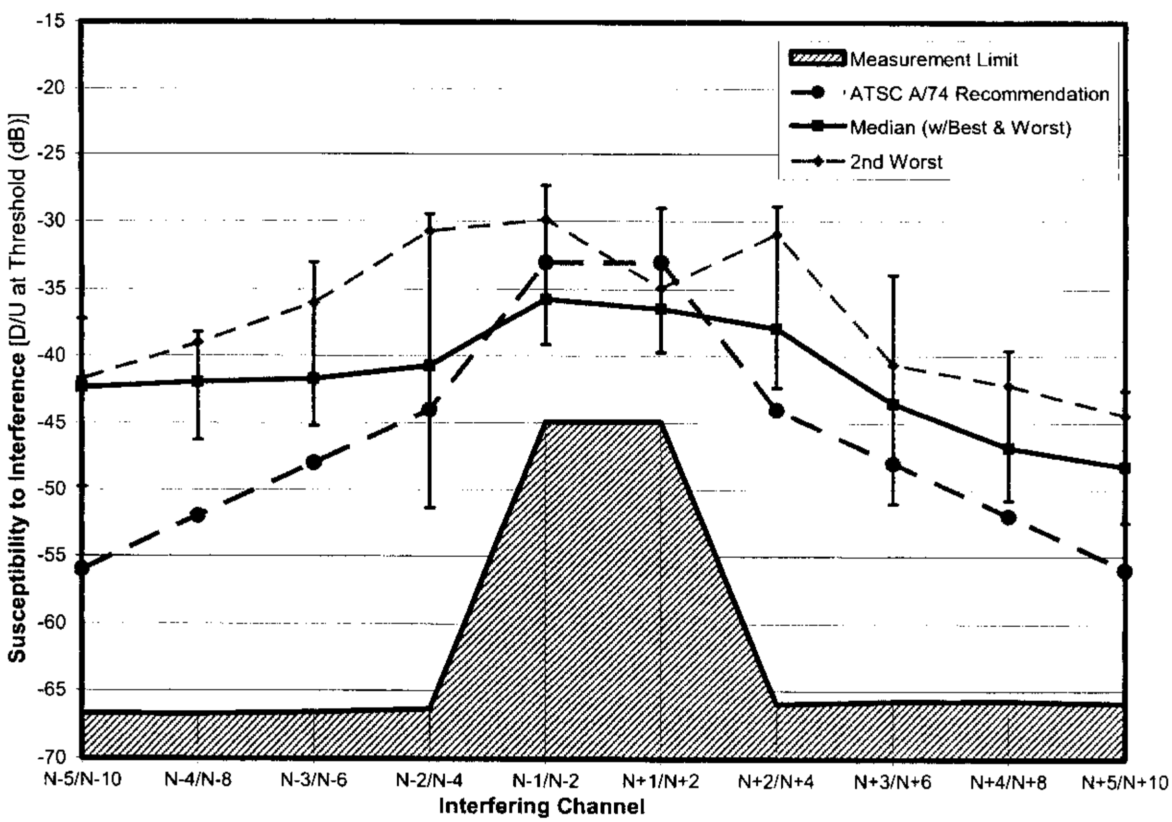


Figure 9-4. Paired-Signal D/U Statistics of 8 receivers at D = -68 dBm on Channel 30

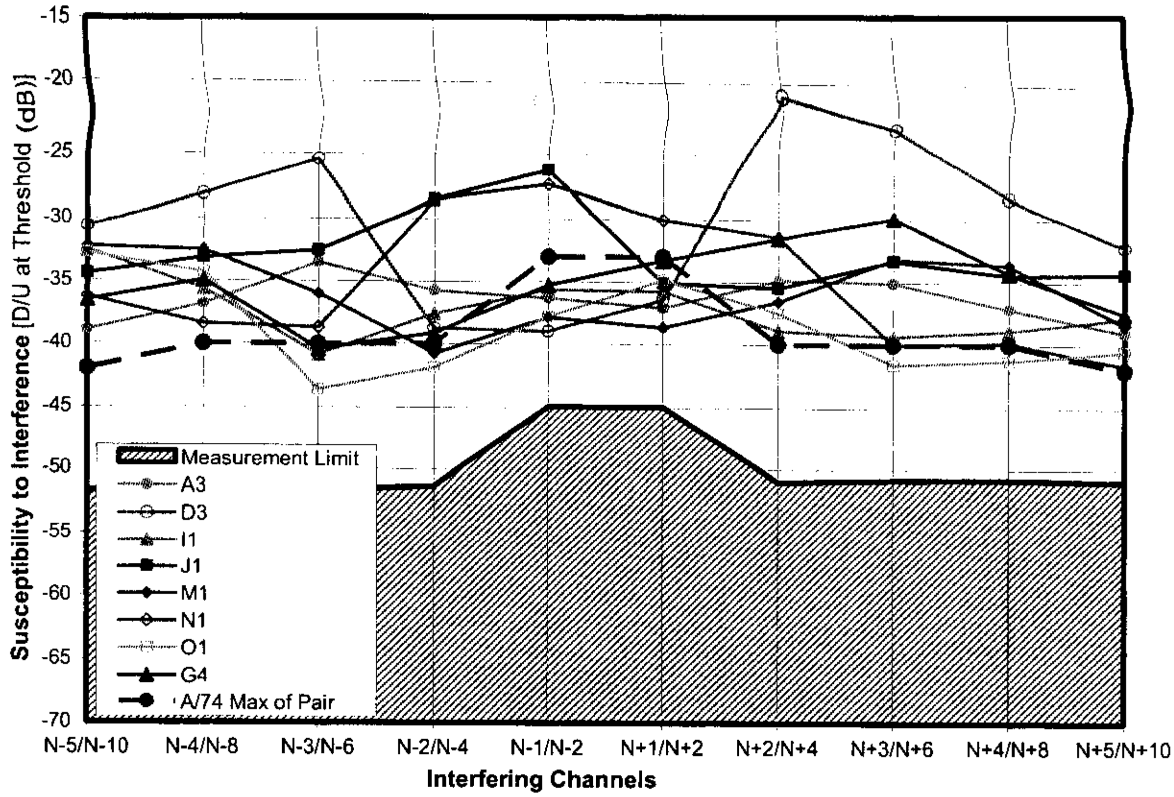


Figure 9-5. Paired-Signal D/U of 8 receivers at D = -53 dBm on Channel 30

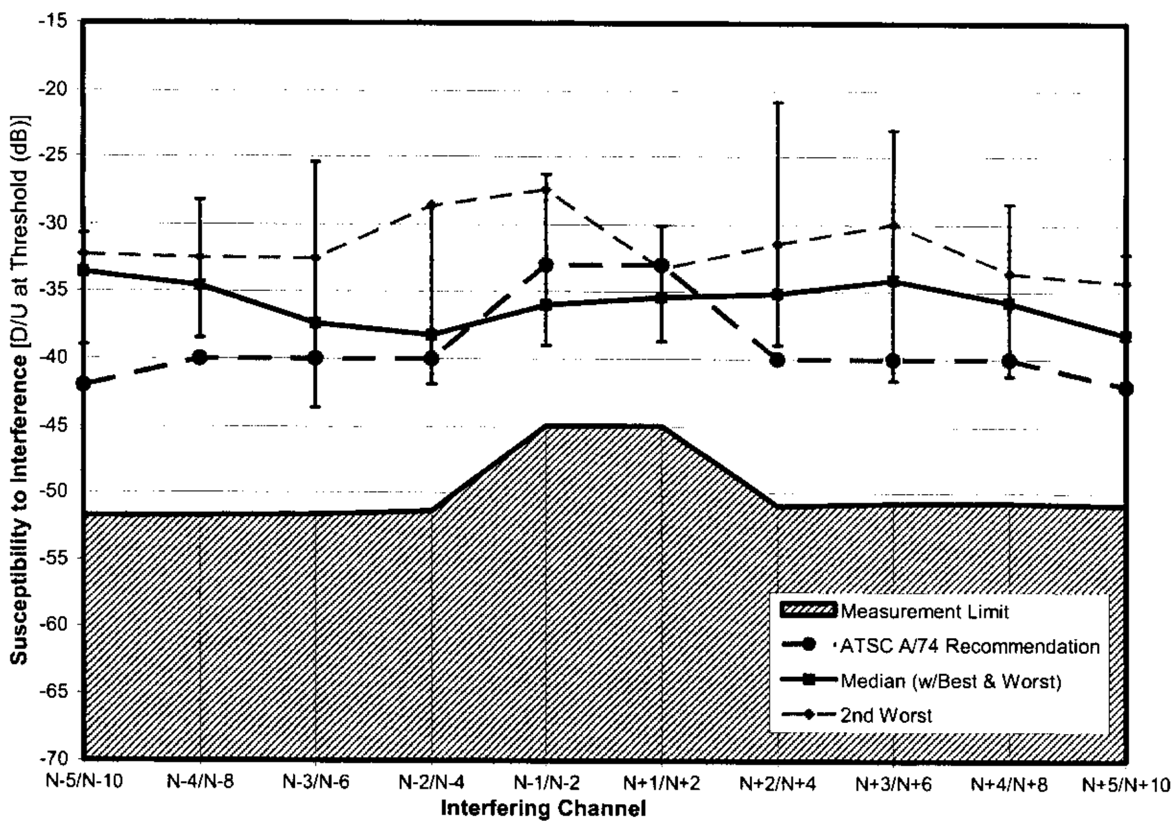


Figure 9-6. Paired-Signal D/U Statistics of 8 receivers at D = -53 dBm on Channel 30

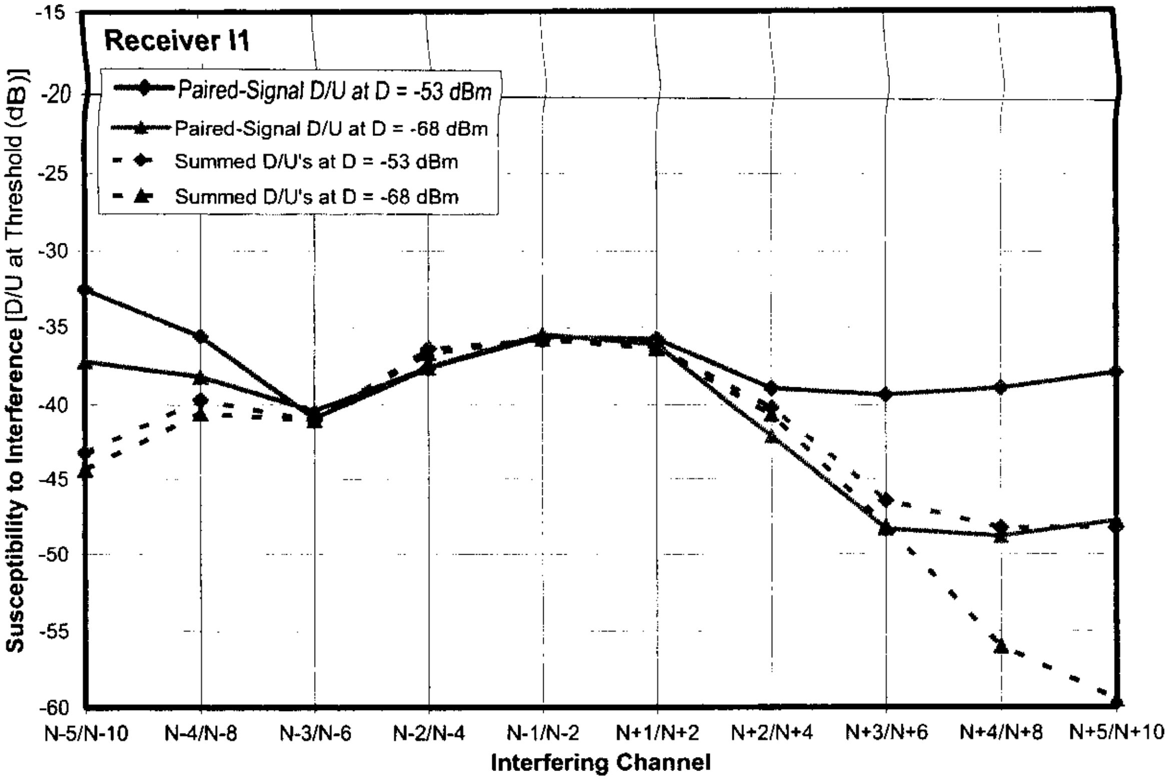


Figure 9-11. Paired-Signal D/U of Receiver I1 on Channel 30 with Summed D/U's as Reference

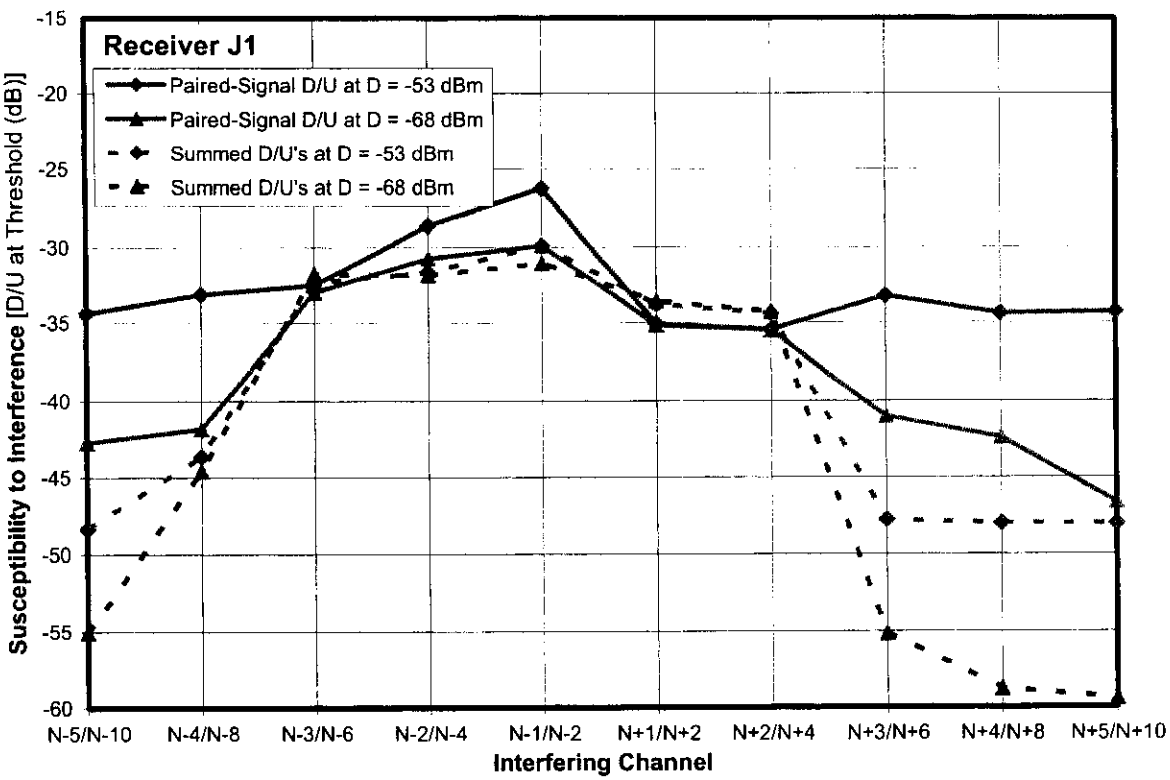


Figure 9-12. Paired-Signal D/U of Receiver J1 on Channel 30 with Summed D/U's as Reference

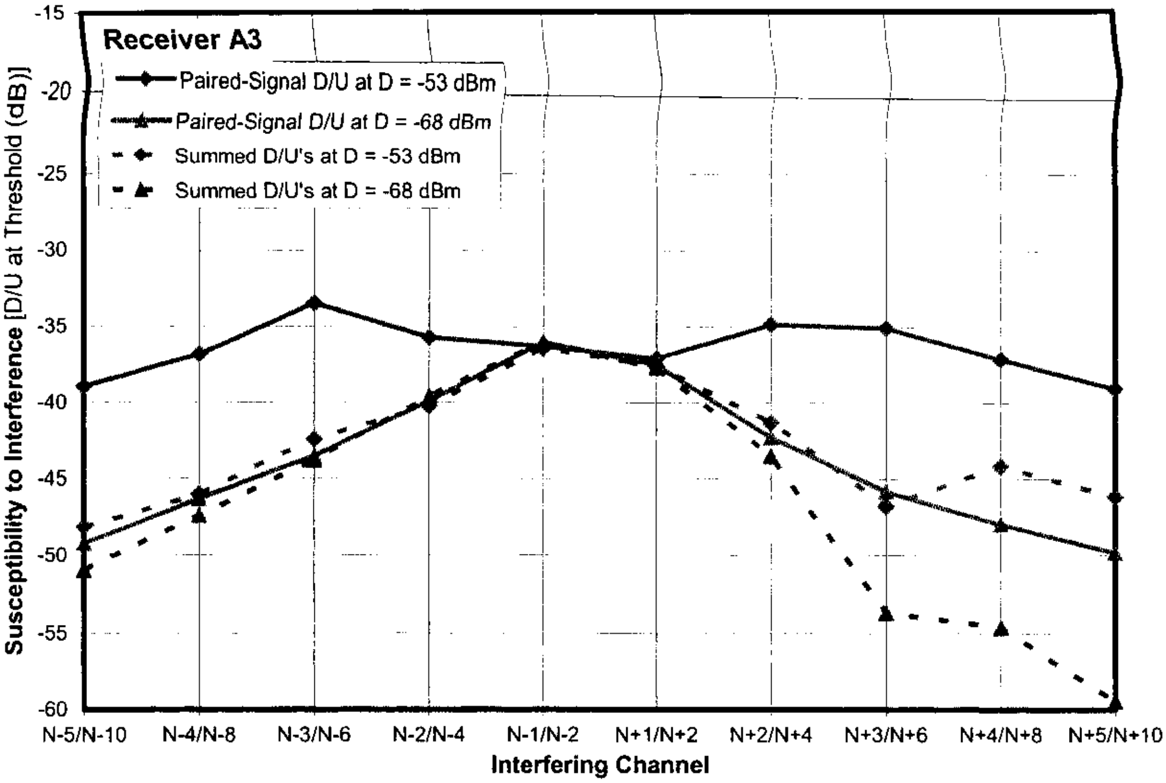


Figure 9-9. Paired-Signal D/U of Receiver A3 on Channel 30 with Summed D/U's as Reference

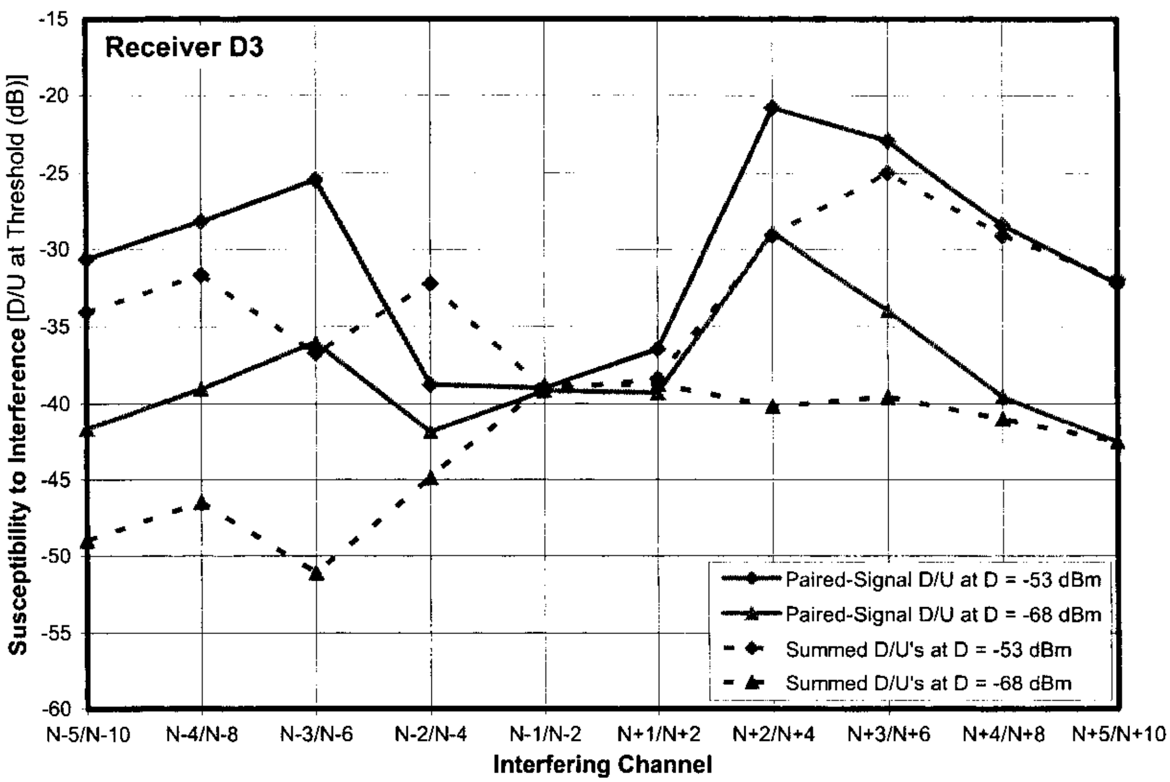


Figure 9-10. Paired-Signal D/U of Receiver D3 on Channel 30 with Summed D/U's as Reference

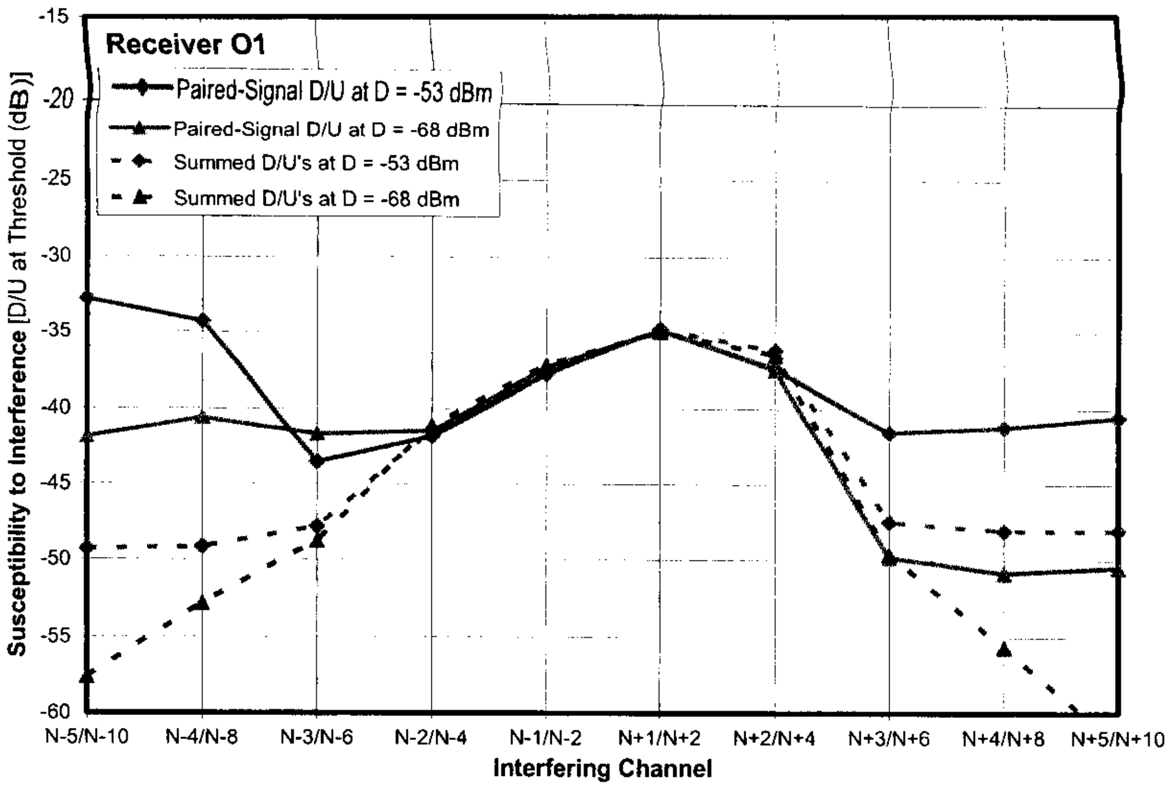


Figure 9-15. Paired-Signal D/U of Receiver O1 on Channel 30 with Summed D/U's as Reference

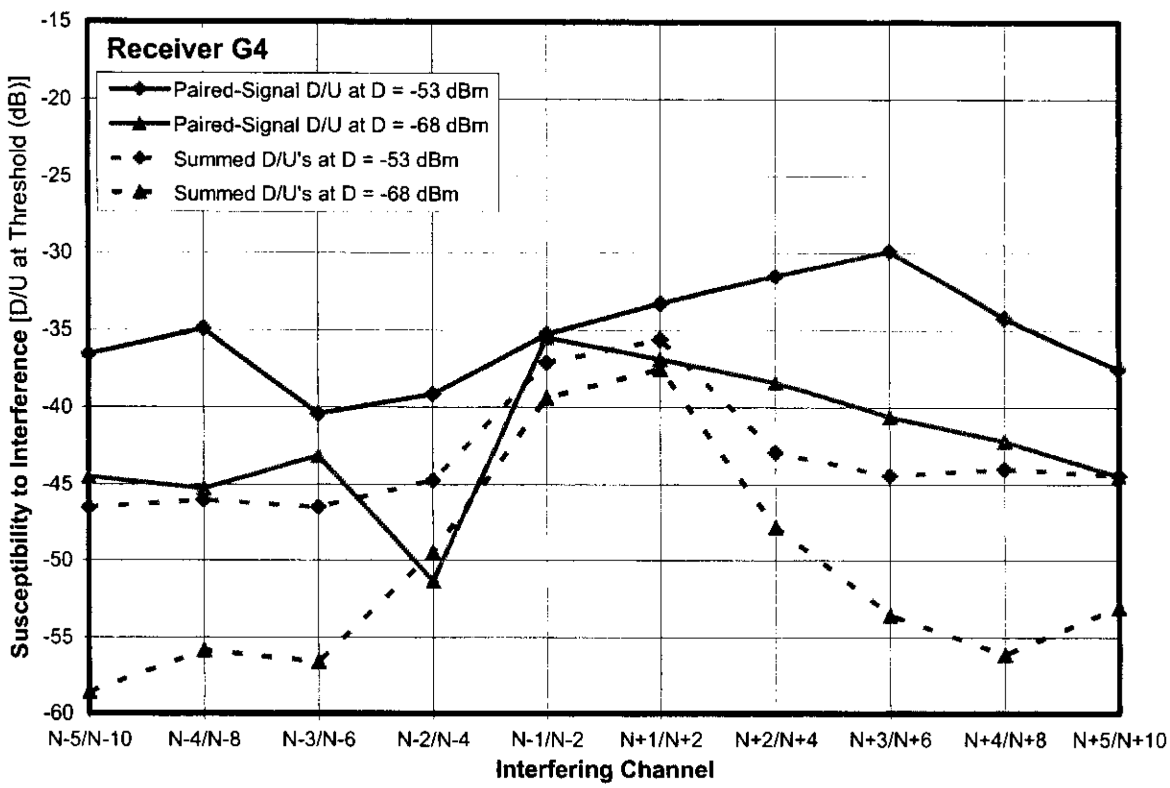


Figure 9-16. Paired-Signal D/U of Receiver G4 on Channel 30 with Summed D/U's as Reference

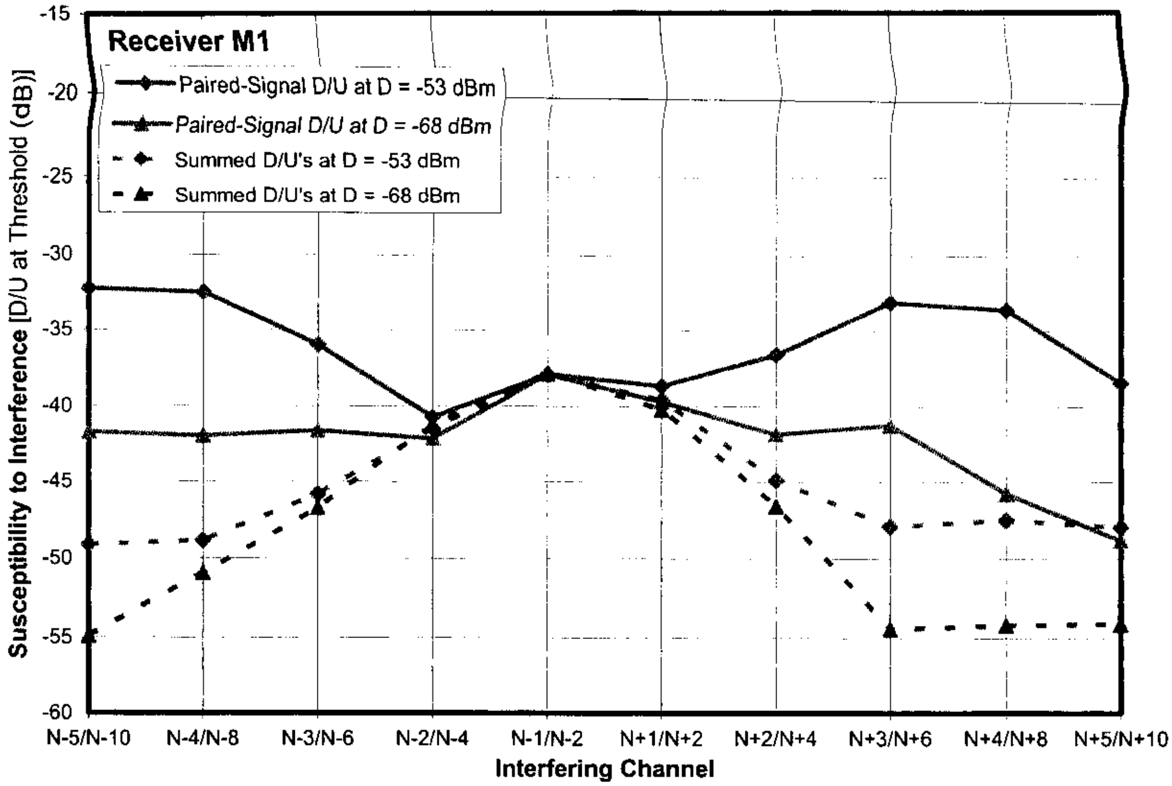


Figure 9-13. Paired-Signal D/U of Receiver M1 on Channel 30 with Summed D/U's as Reference

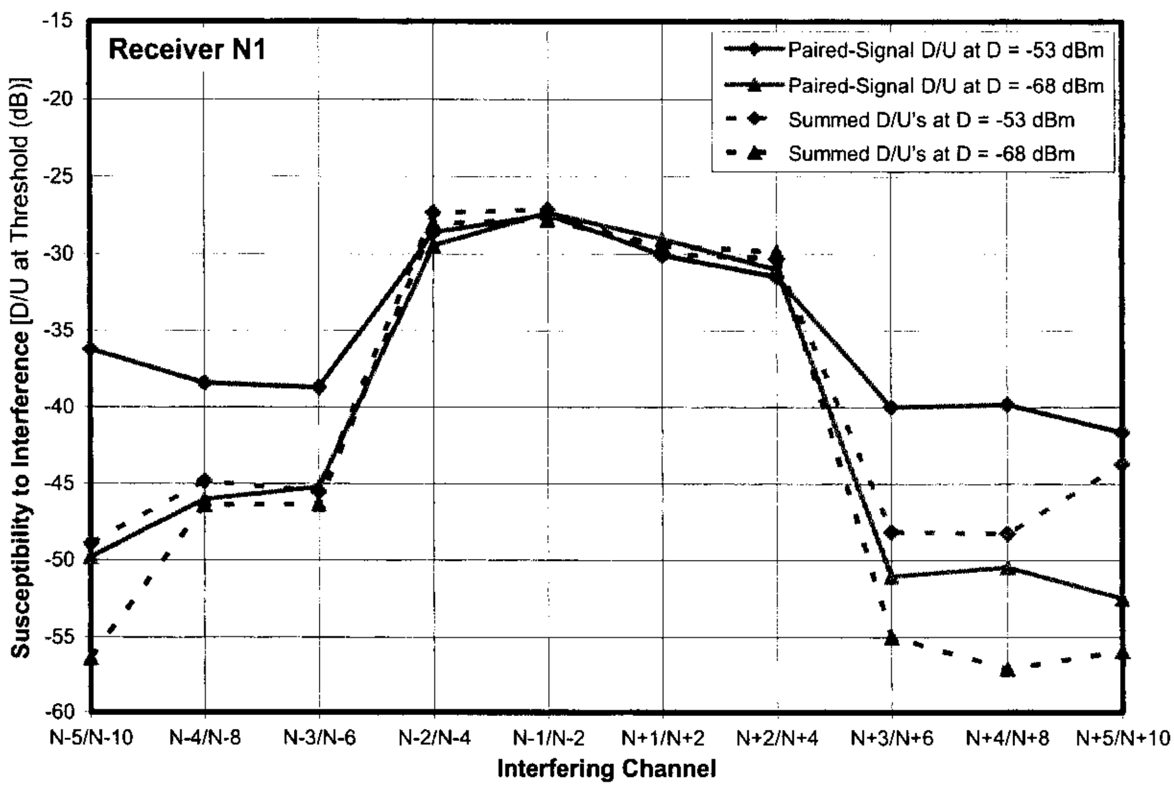


Figure 9-14. Paired-Signal D/U of Receiver N1 on Channel 30 with Summed D/U's as Reference

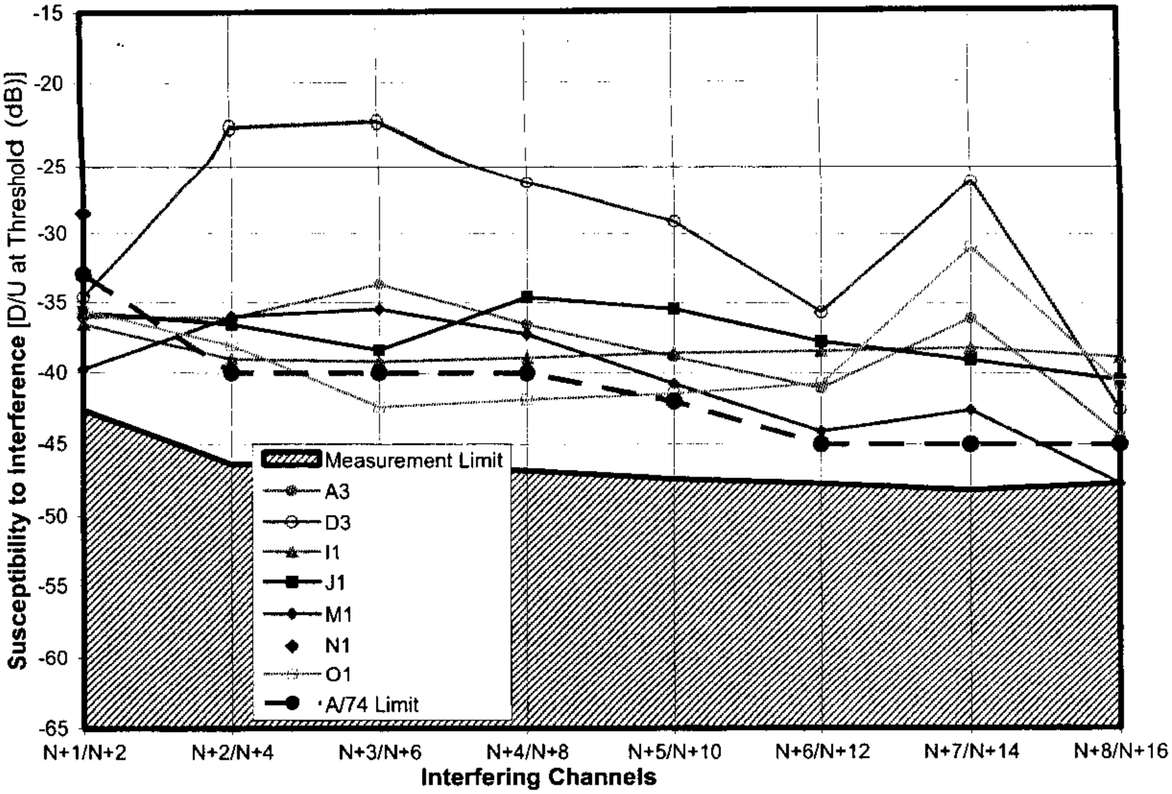


Figure 9-19. Paired-Signal D/U of 7 receivers at D = -53 dBm on Channel 51

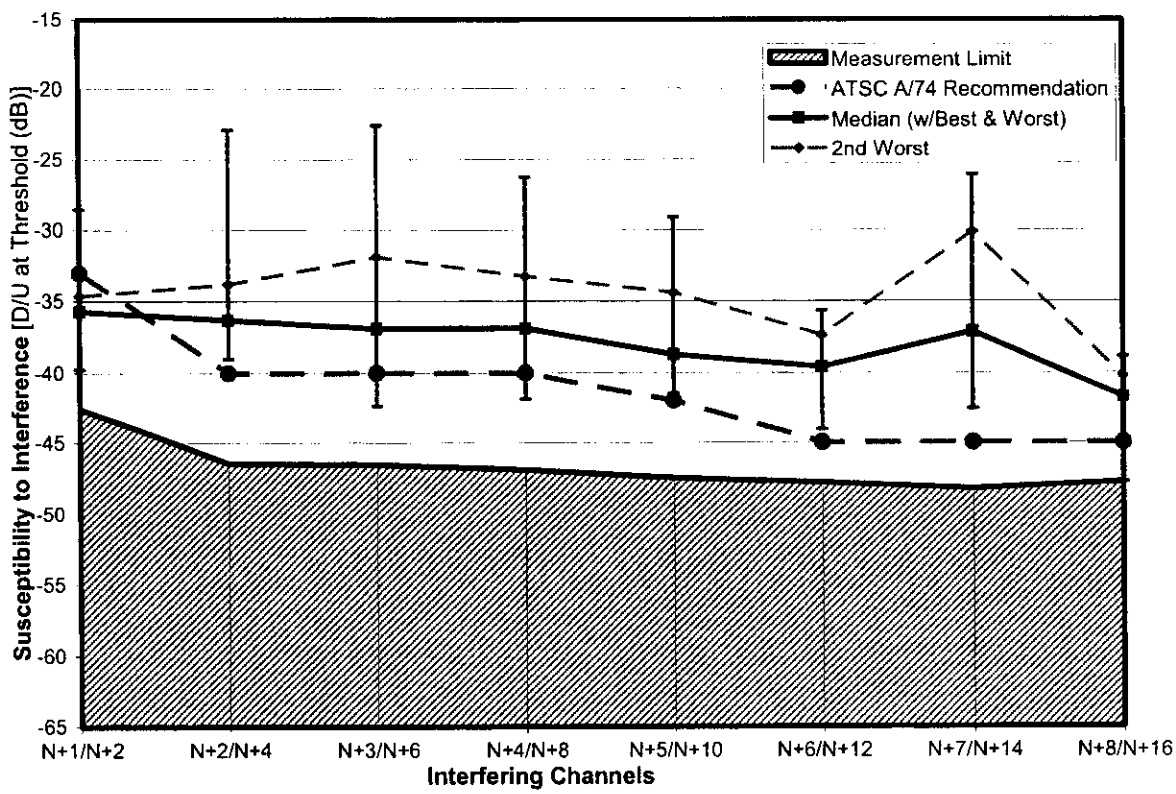


Figure 9-20. Paired-Signal D/U Statistics of 6 receivers at D = -53 dBm on Channel 51

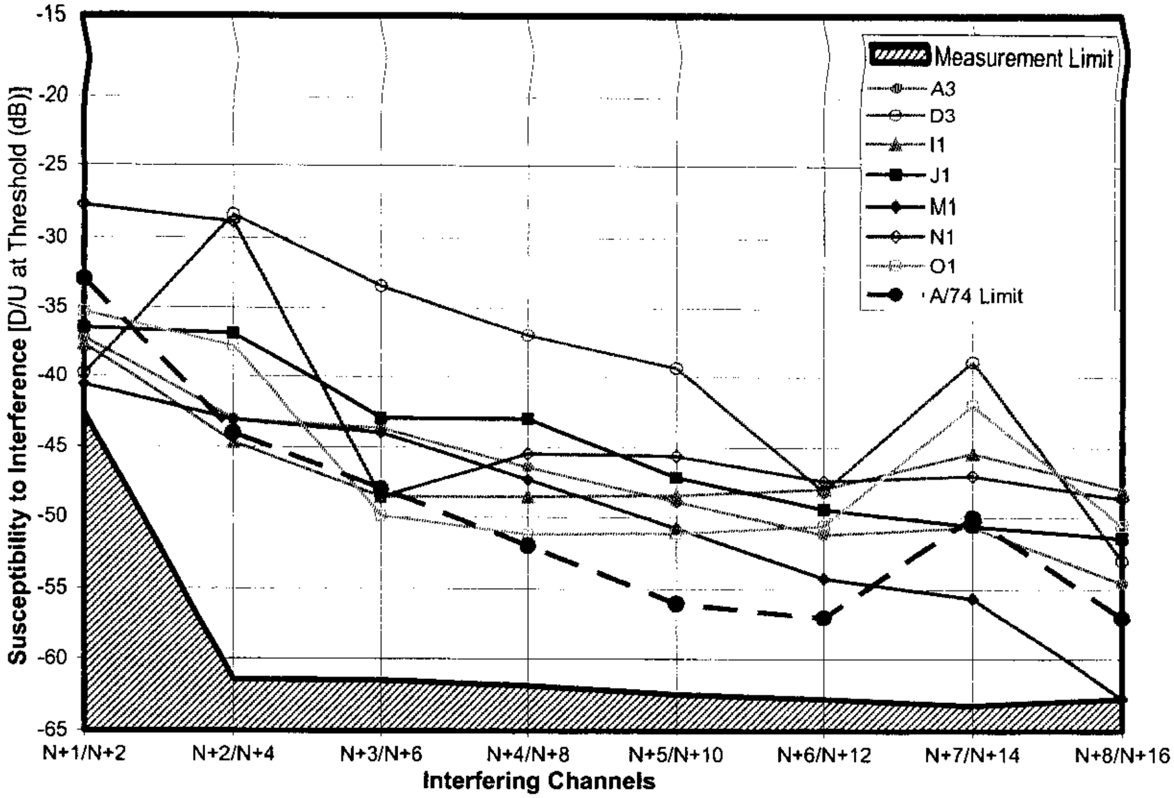


Figure 9-17. Paired-Signal D/U of 7 receivers at D = -68 dBm on Channel 51

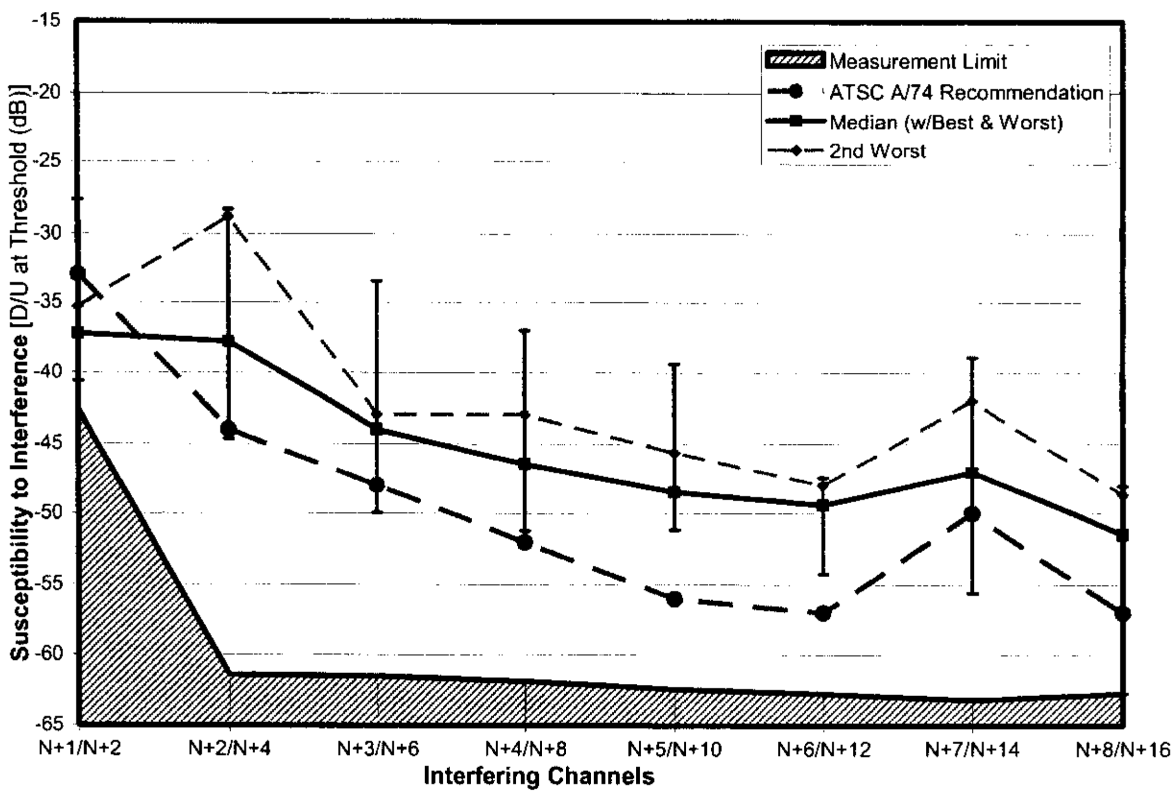


Figure 9-18. Paired-Signal D/U Statistics of 7 receivers at D = -68 dBm on Channel 51

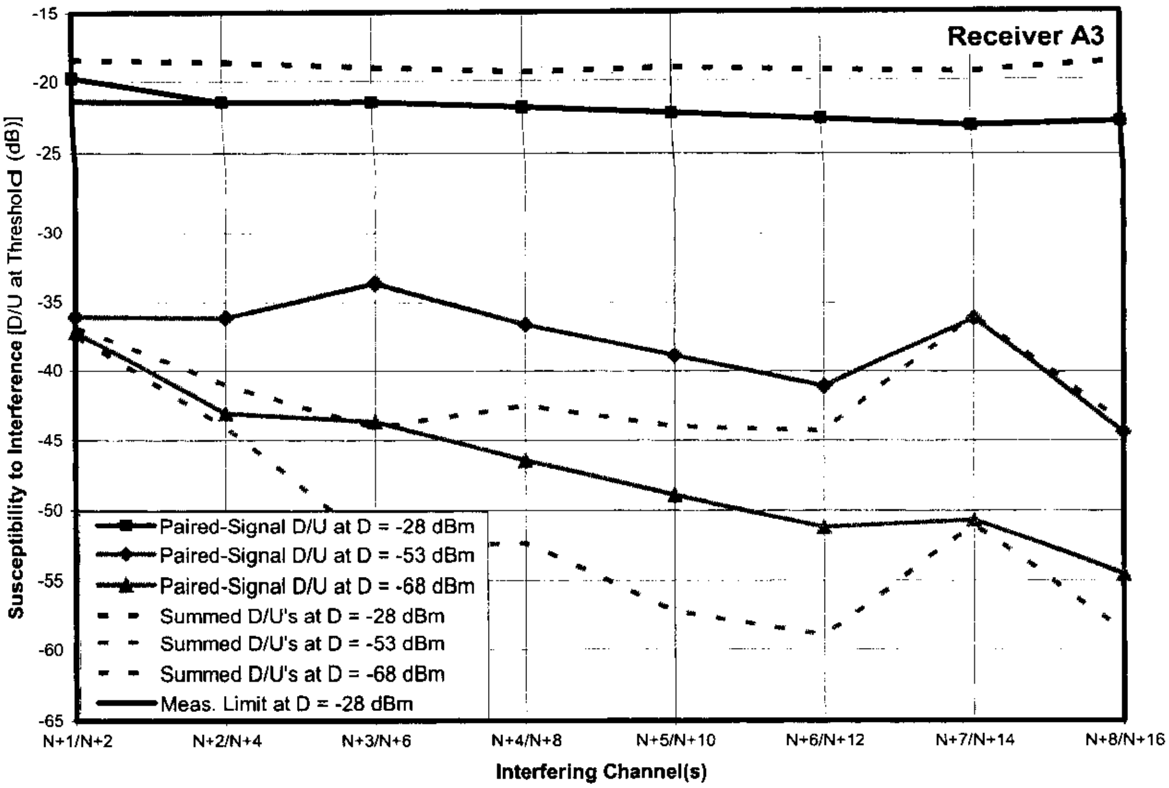


Figure 9-23. Paired-Signal D/U of Receiver A3 on Channel 51 with Summed D/U's as Reference

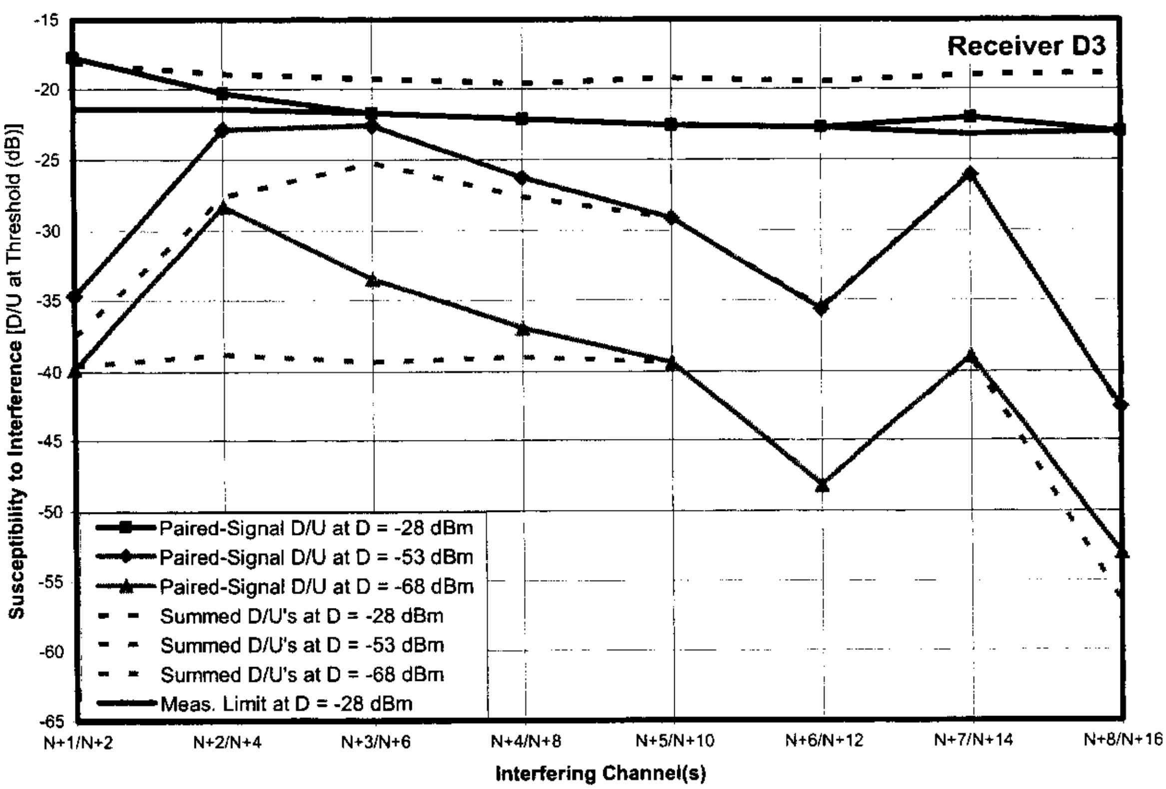


Figure 9-24. Paired-Signal D/U of Receiver D3 on Channel 51 with Summed D/U's as Reference

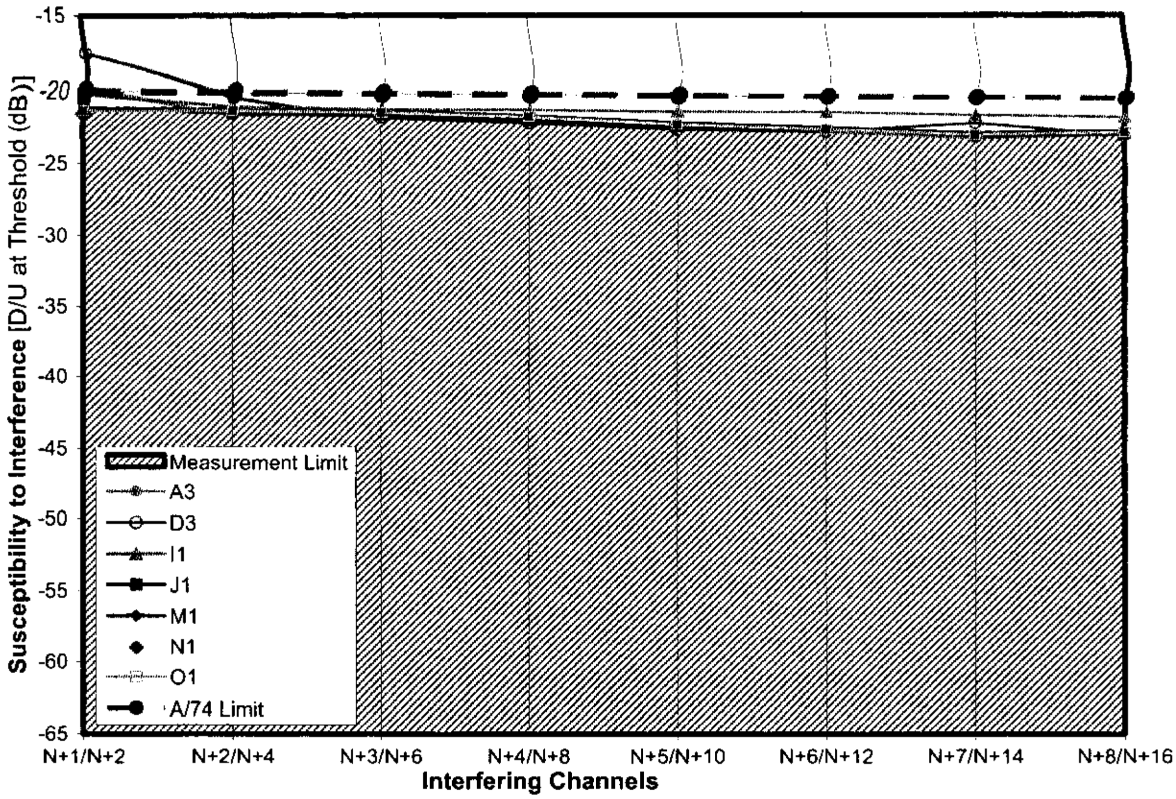


Figure 9-21. Paired-Signal D/U of 7 receivers at D = -28 dBm on Channel 51

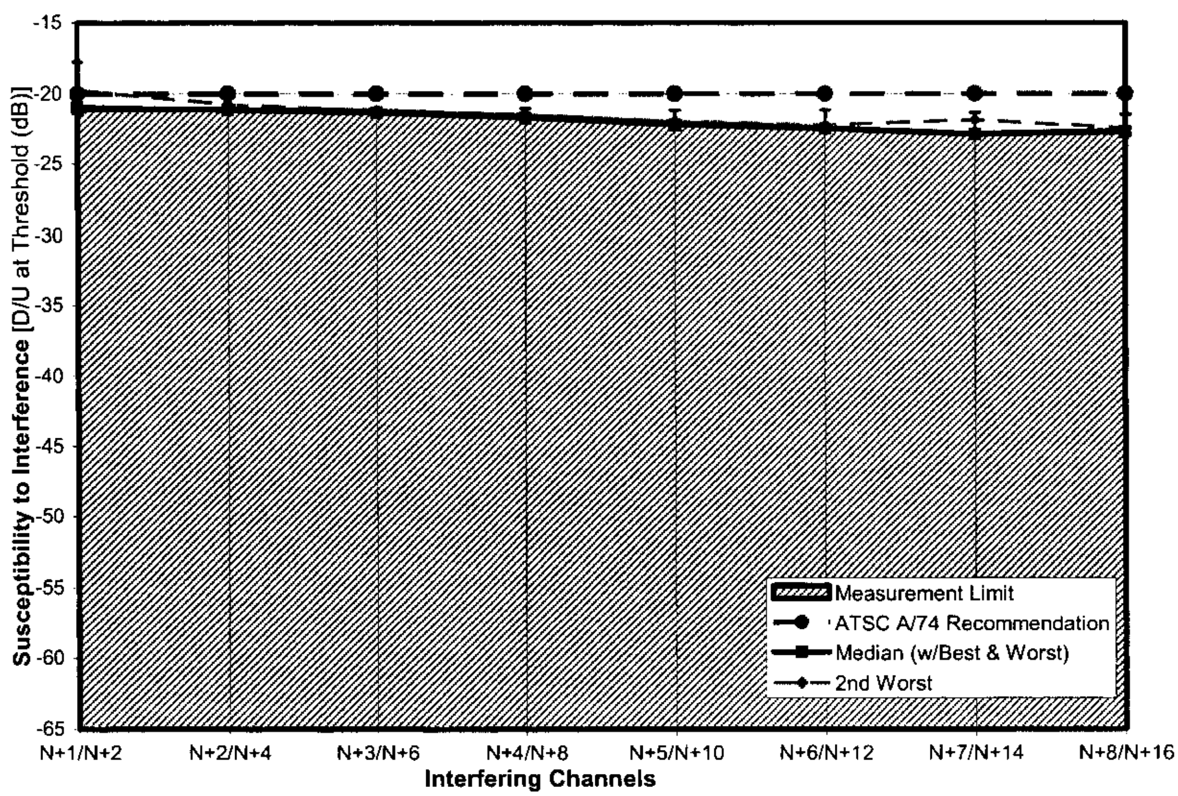


Figure 9-22. Paired-Signal D/U Statistics of 6 receivers at D = -28 dBm on Channel 51

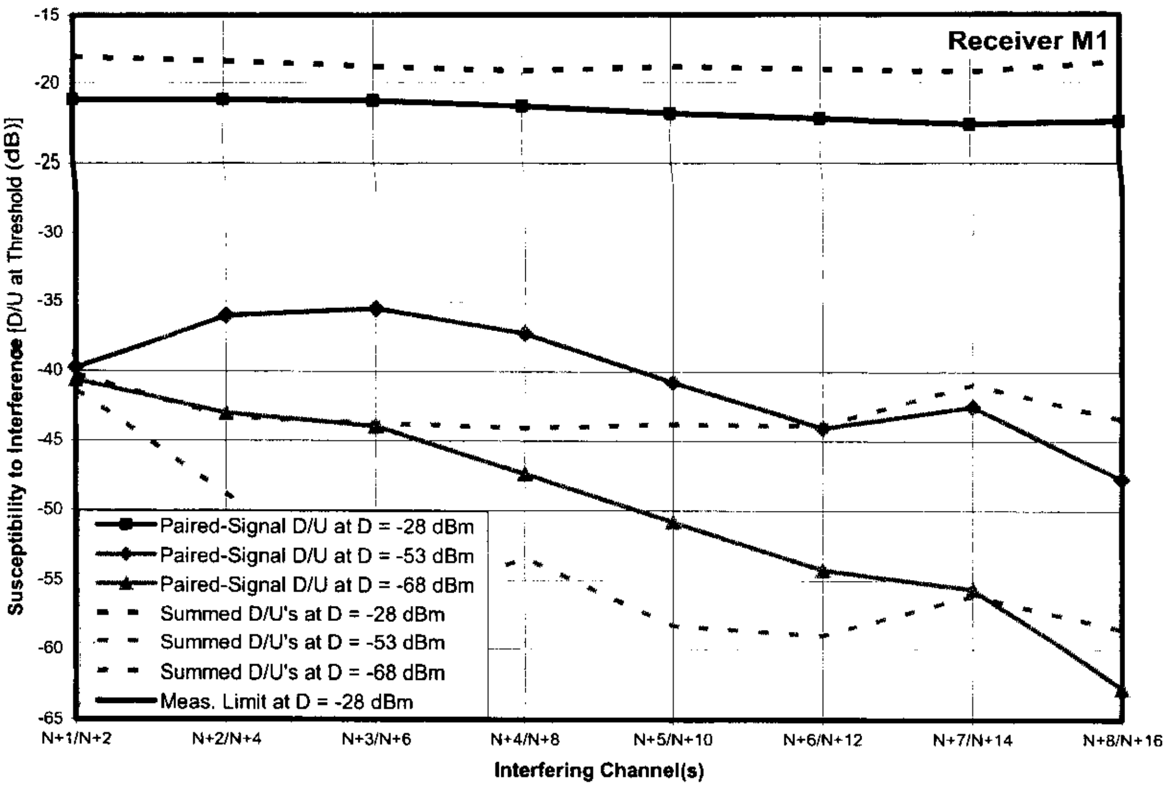


Figure 9-27. Paired-Signal D/U of Receiver M1 on Channel 51 with Summed D/U's as Reference

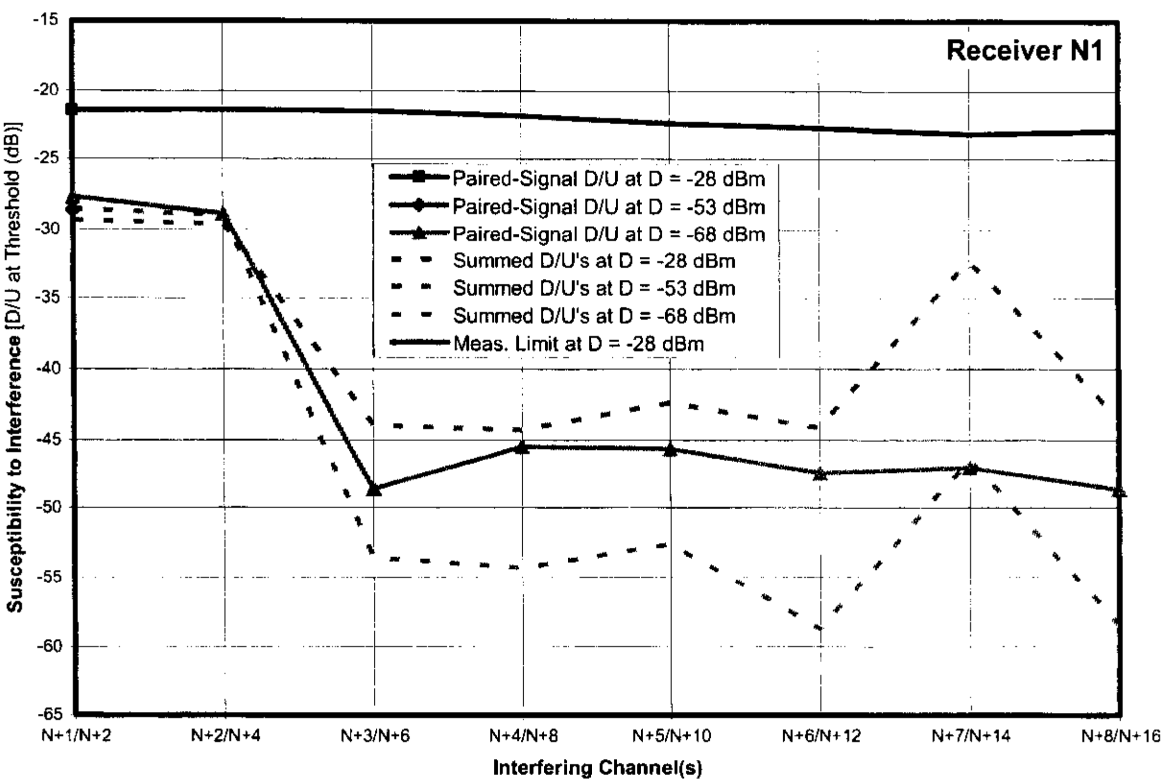


Figure 9-28. Paired-Signal D/U of Receiver N1 on Channel 51 with Summed D/U's as Reference

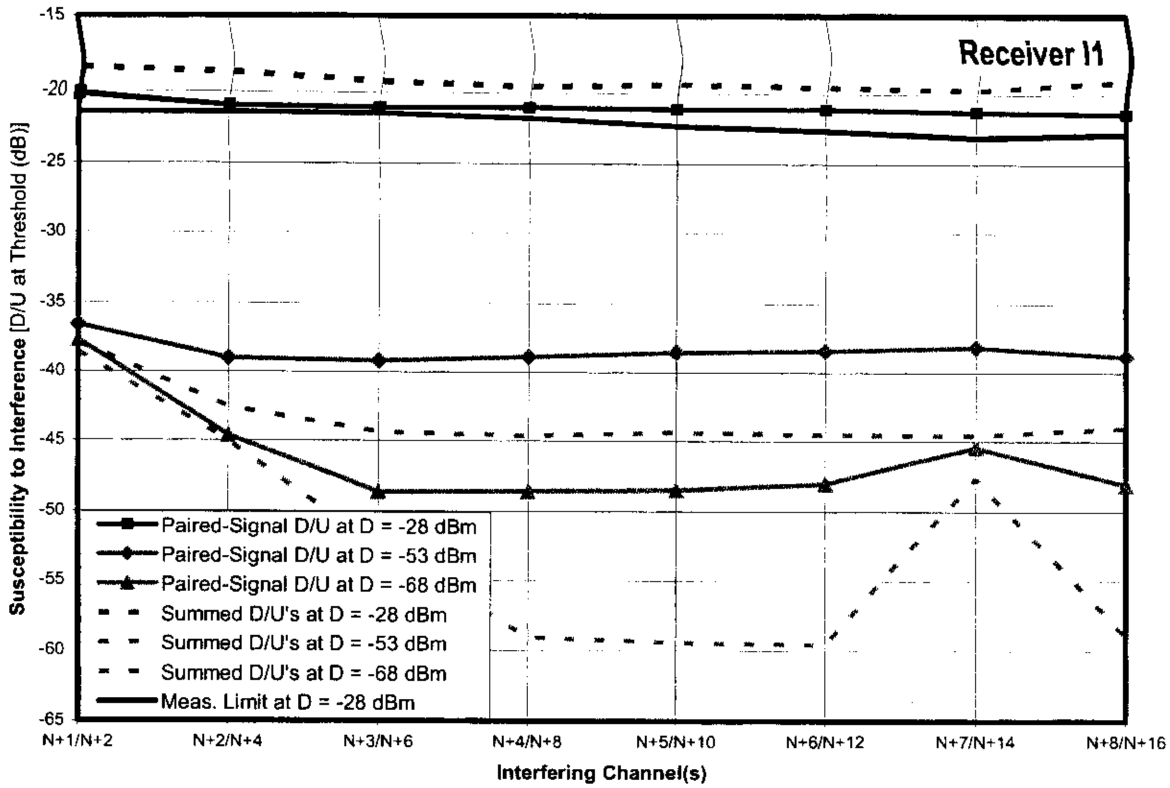


Figure 9-25. Paired-Signal D/U of Receiver I1 on Channel 51 with Summed D/U's as Reference

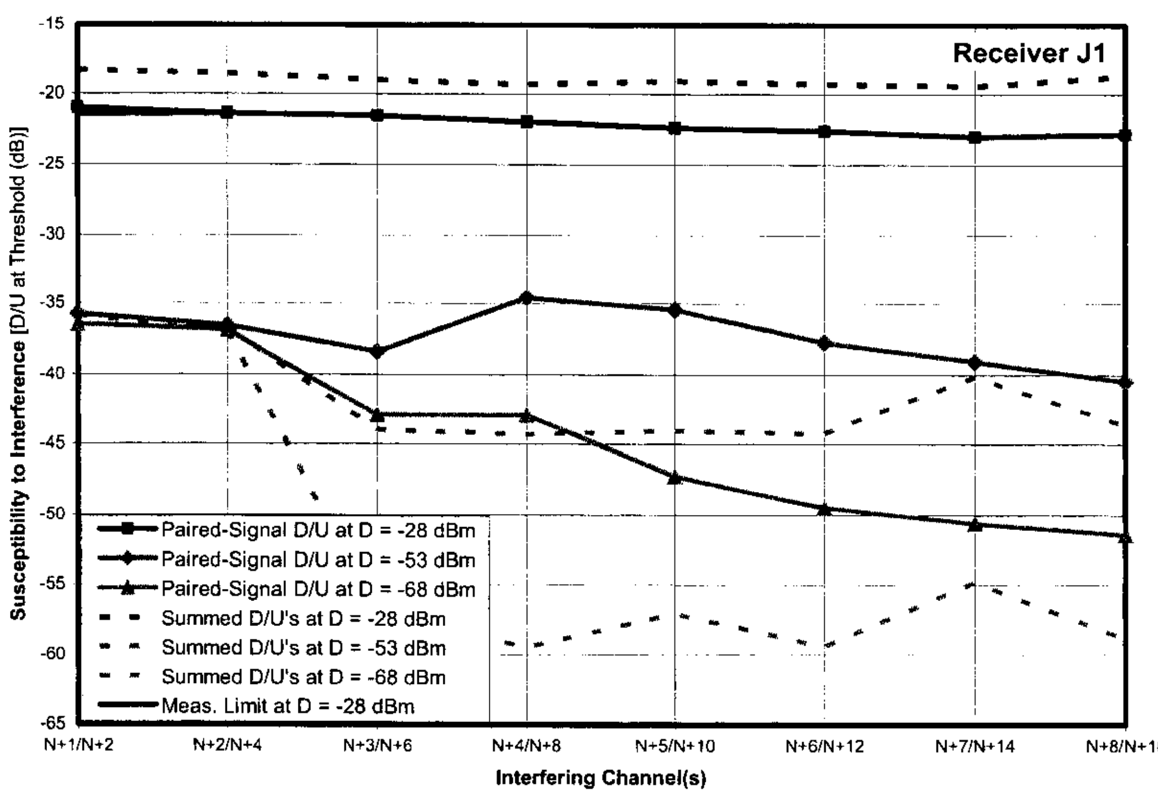


Figure 9-26. Paired-Signal D/U of Receiver J1 on Channel 51 with Summed D/U's as Reference

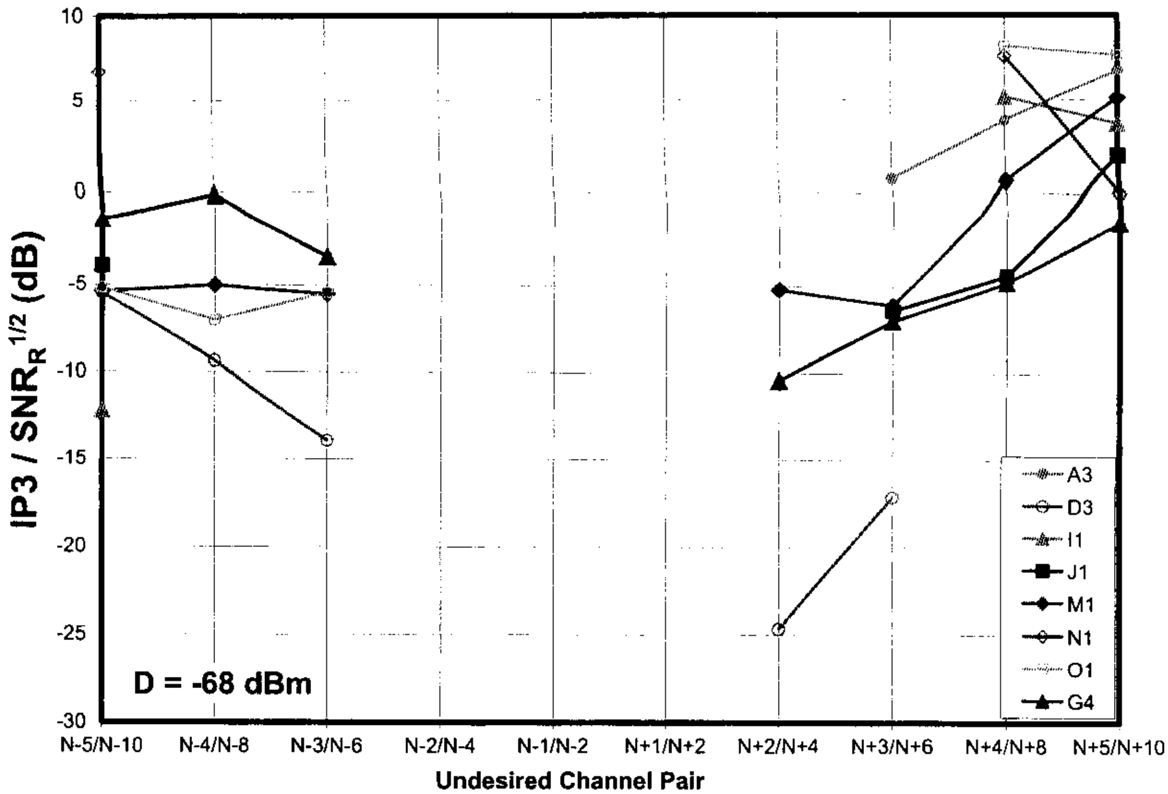


Figure 9-30. Third-Order Intercept Point Parameter with Desired Signal = -68 dBm on Channel 30

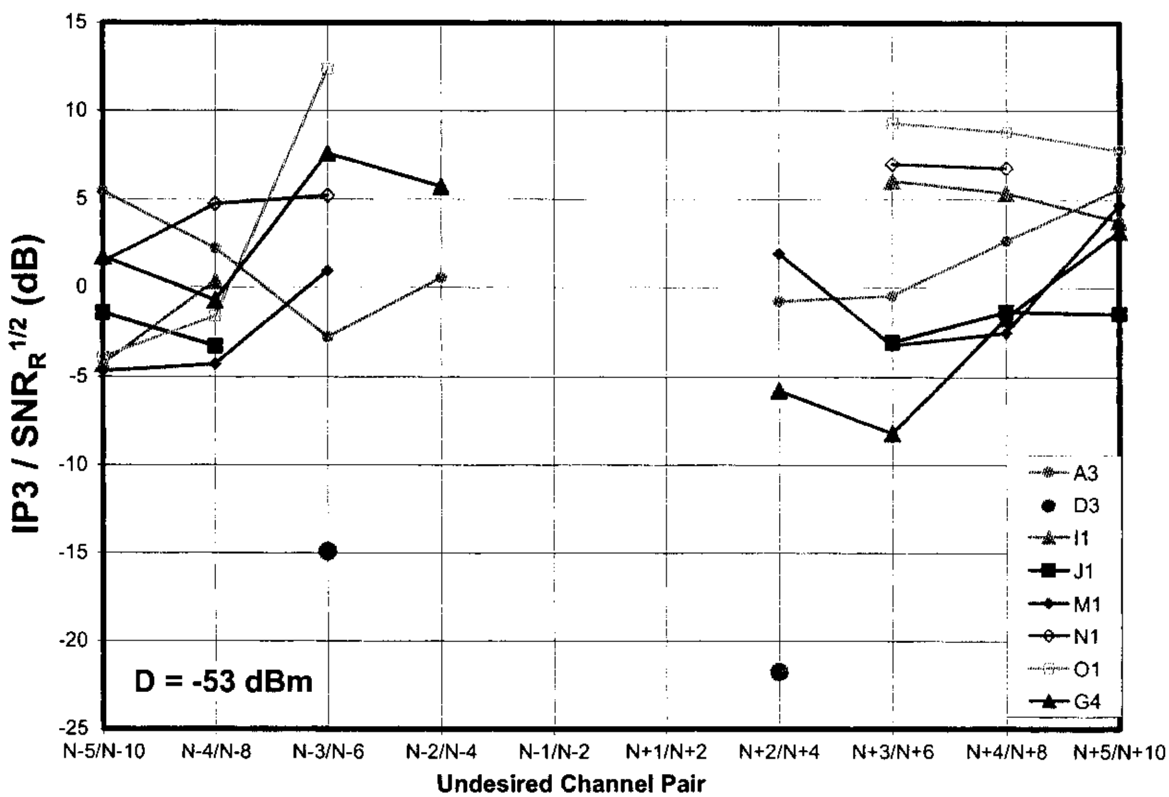


Figure 9-31. Third-Order Intercept Point Parameter with Desired Signal = -53 dBm on Channel 30

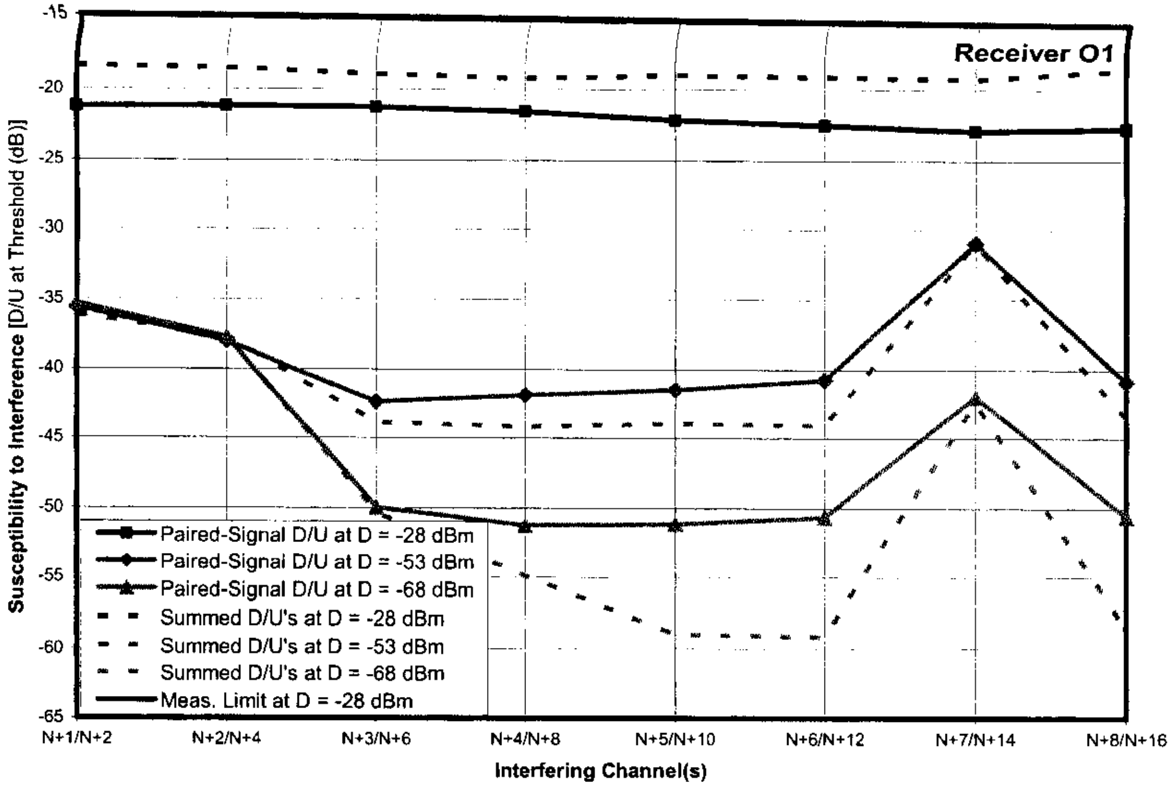


Figure 9-29. Paired-Signal D/U of Receiver O1 on Channel 51 with Summed D/U's as Reference

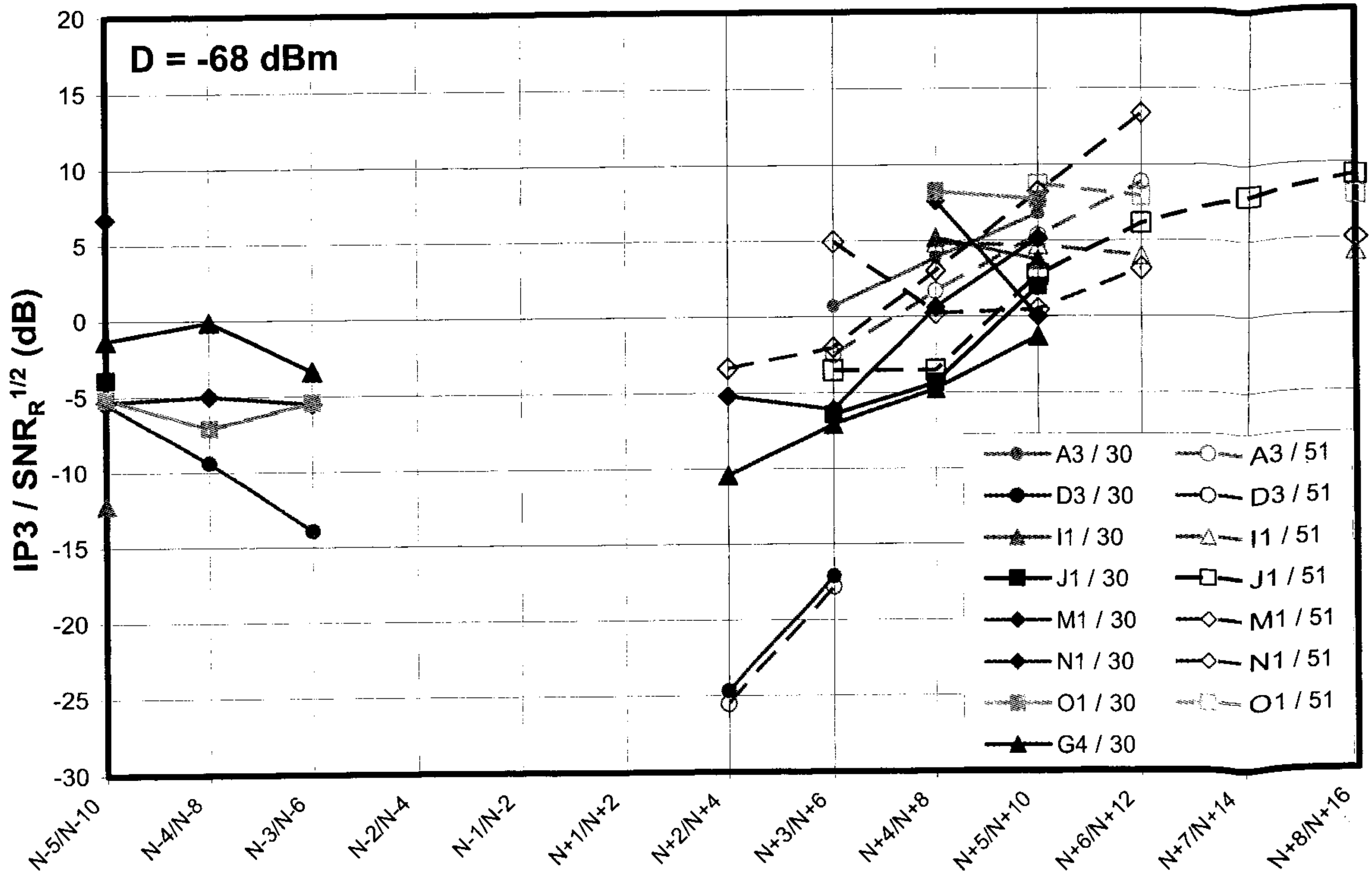


Figure 9-34. Third-Order Intercept Point Parameter—Channel 30/51 Comparison

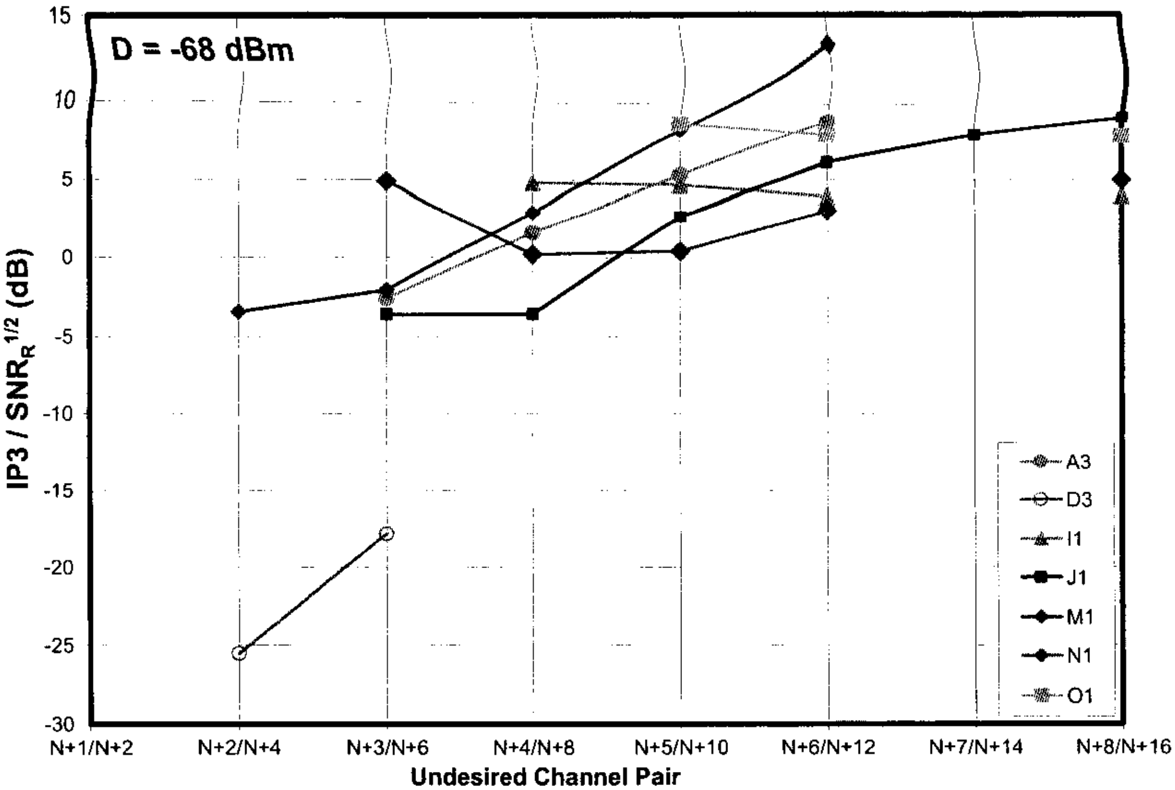


Figure 9-32. Third-Order Intercept Point Parameter with Desired Signal = -68 dBm on Channel 51

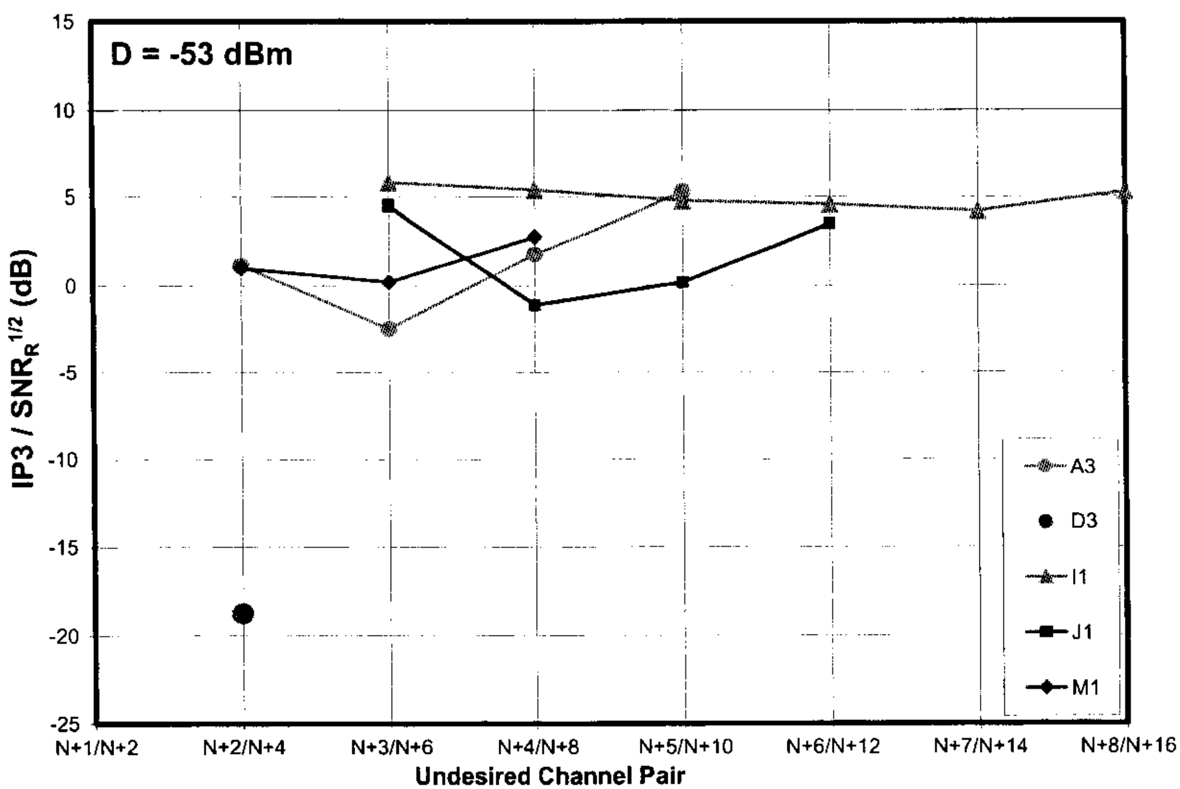


Figure 9-33. Third-Order Intercept Point Parameter with Desired Signal = -53 dBm on Channel 51

CHAPTER 10
IM3 WITH PAIRED SIGNALS OF UNEQUAL AMPLITUDES

The previous chapter showed the results of D/U measurements on eight receivers for pairs of undesired signals that were equal in power. In this chapter, we select two receivers and one channel offset pair for each for additional measurements with unequal undesired input signals. A model of the results is presented to allow measurements from the previous chapter to be to be extended to unequal signal levels on the other receivers. It will be seen that the model performs best at low desired signal levels.

MEASUREMENTS ON TWO RECEIVERS

The tests for this chapter were performed on receiver G4 with an undesired signal pair at N+2/N+4 and receiver M1 with an undesired signal pair at N+3/N+6. The selections of these receivers and channel offsets were based on their relatively high (though not the highest) differences between paired-signal D/U and summed D/U measurements, as presented in Chapter 9. This selection criterion ensured that the tests would be performed on receivers that exhibited easily measurable IM3 effects—at least for paired signals of equal levels. Plots of paired-signal D/U's and summed D/U's for these receivers were shown in Figures 9-16 and 9-13, respectively, in Chapter 9.

Figure 10-1 shows measurements of threshold signal levels for a pair of undesired signals on N+2 and N+4 for receiver G4. The three curves correspond to three desired signal levels: -53 dBm, -68 dBm, and D_{MIN} + 3 dB. The measurements were performed by attenuating one undesired signal with respect to the other, and then adjusting an attenuator that affected both undesired signal levels until TOV for the DTV receiver was found.* The X-axis shows the signal level of the undesired signal on channel N+2. The Y-axis shows the level of the undesired signal on channel N+4. The dashed lines represent a model, to be discussed in the next section.

If one moves down the chart toward very low signal levels on N+4, each curve asymptotically approaches the respective threshold level for N+2 alone. Similarly, moving leftward on the chart toward very low levels on N+2 causes at least one curve (that for D_{MIN} + 3 dB) to asymptotically approach the threshold value for N+4 alone.† In between these two conditions is the region where IM3 between the pair of signals is the dominant interference mechanism.

Figure 10-2 shows the same type of measurement performed on receiver M1. This receiver exhibited very odd behavior when the undesired signal power on N+3 (U_{N+3}) was between -27 and -21 dBm. As U_{N+3} is increased in this range, the upper two curves exhibit first a dip in U_{N+6} relative to the previous trajectory, then a sharp increase, and finally a return back down to the previous trajectory. The lower curve exhibits the dip, but the threshold value of U_{N+3} is reached before subsequent behavior had an opportunity to occur.

Figure 10-3 isolates the curve corresponding to a desired signal power of -68 dBm and adds a shading effect to illustrate the bizarreness of the behavior. Consider moving along the solid diagonal line, representing equal values of undesired signals, while the desired signal level remains at -68 dBm. Beginning at the lower left and moving rightward, DTV reception is visually flawless. When each of the

---

* Referring to the block diagram in Figure 4-1, the output level of one of the two "AWGN" sources was lowered with respect to the other. Step Attenuator-U, which operates on the sum of the two sources, was then adjusted to find the TOV point.

† We note that this is the receiver that exhibited intermittent changes in performance of up to 6 dB, as noted in Chapter 7. Consequently, there is approximately a 6-dB mismatch between three of the threshold shown here and equivalent measurements presented elsewhere in this report.

- A vertical line represents the threshold value of U_{N+K} in the absence of an undesired signal at N+2K; this portion of the model is based on direct measurement of the threshold under that condition;
- A diagonal line with a slope of -2 dB/dB represents the IM3 contribution to interference based on the formulas above; the required value of IP3 / $SNR_R^{1/2}$ was computed by measurement of threshold with $U_{N+K} = U_{N+2K}$.

Thus, three measurements (indicated by the black circles) were required to create each modeled performance curve. Given that those same three measurements exist for each of the eight receivers at various channel offsets, we can apply the modeling technique to the other receivers and other channel offsets. We choose to do this only at the lower signal levels (D = -68 dBm and below) since the model appears to be a better fit to measurements at such levels. (At higher levels, AGC is more likely to influence the results.)

We note that, even if the AGC did not engage to reduce gain prior to the IM3-generating nonlinearity during measurement of the threshold for equal-powered undesired signals, it is still possible that it might engage under some non-equal undesired signal conditions. This is more likely to occur on the basis of U_{N+K}, since it is likely to be subjected to less attenuation by the tuner's tracking filter than is U_{N+2K}. If the AGC does engage on U_{N+K}, the IM3 segment of the model curve will switch at that point from being a diagonal line to a horizontal line extending rightward from the AGC engagement point (per Appendix B). ***Since we haven't attempted to determine AGC thresholds for each case, the reader should recognize that the curves shown in the models presented in this chapter will be invalid to the right of such an AGC engagement point, if one occurs.*** In Chapter 14, we identify one such case.

Models for D = -68 dBm

Figures 10-4 through 10-10 show paired-signal IM3 models for the eight DTV receivers at a desired signal level of -68 dBm. Each graph represents one channel-offset pair—*e.g.*, N-5/N-10 for the first. Each graph contains one curve for each DTV receiver for which an IP3 / $SNR_R^{1/2}$ was determined in Table 9-3.

No plots are shown for the first-adjacent channel cases (N-1/N-2 and N+1/N+2) because measurements presented in Chapter 9 were not adequate to ensure that a paired-signal IM3 effect was measured for those channels (as opposed to individual-channel effects). Chapter 11 will show, in detail, that the paired-signal IM3 on N+1/N+2 is limited to certain regions of the amplitude range for receiver D3 (at least for equal amplitude undesired signals).

Each curve shows that the presence of one undesired signal can affect the TV receiver's susceptibility to the other. As an example, we examine the curve corresponding to receiver D3 in Figure 10-5, where K is -4 (*i.e.*, the channel pair is N-4/N-8). Starting at the top left end of that curve, we see that the TV is susceptible to interference from an undesired signal at -13 dBm on channel N+2K (y-axis). Moving to the right, we see that, if an undesired signal is also present on channel N+K at a level exceeding -37 dBm, the susceptibility of the receiver to interference on channel N+2K will increase (*i.e.*, the receiver will be affected by smaller undesired signals on that channel). As the level of the undesired signal on channel N+K increases, the signal level on channel N+2K necessary to cause interference drops by 2 dB for each 1-dB increase in power on channel N+K—eventually reaching -45 dBm when the undesired signal on channel N+K reaches -21 dB. Similarly, we can view the undesired signal on channel N+2K as causing the TV to be more susceptible to interference from channel N+K.

This example could be applied to the case in which a desired signal—broadcast from a DTV station on channel N—is received at a level of -68 dBm at the input to a DTV receiver and another DTV broadcast on channel N-4 is the first undesired signal. The analysis described above could be used to predict the vulnerability of the DTV receiver to emissions from a white-space device or another DTV station operating on channel N-8, as a function of the undesired signal level on channel N-4 at the input to the receiver.

Table 10-1 summarizes the information in the model plots. Note that the statistics provided here apply to the subset of combinations of channel offsets and TVs for which a measurement of IP3 / $SNR_R^{1/2}$ was obtained. In general, the greatest susceptibility to interference is predicted to be on channel N+2K when a large signal is present on N+K. If no undesired signal is present on channel N+K, the receivers can tolerate undesired signal levels as high as -27 to -1 dBm on N+2K. With an undesired signal on N+2K, the receivers are predicted to be susceptible to undesired signal powers as low as -79 to -28 dBm—an increase in susceptibility ranging from 23 to 63 dBm. The signal level on N+K necessary to cause such an increase in interference susceptibility can range from -28 to -3 dBm, but the susceptibility increase begins at levels of -45 to -24 dBm on channel N+2K.

If one were interested in determining what undesired signal level could cause interference to DTV reception, one might consider two different approaches with respect to IM3 from paired signals:
(1) Identify a level that could cause interference ***if*** a similar signal level happens to occur at another channel offset that would place IM3 products in the desired channel;
(2) Identify levels that will cause interference given a specific knowledge of signal levels that already exist on other channels that might combine with the signal of interest to cause IM3.

In case (1) analysis could be performed based on the equal-power paired-signal test results from Chapter 9 (or summary charts presented in Chapter 15 of this report). In case (2), the modeled results in this chapter could provide a basis for analysis.

Table 10-1. Range of Impact of IM3 from Pairs of Undesired Signals When D = -68 dBm

	Statistics of Undesired Signal Levels (dBm)				
	Min.	**Median**	**Mean**	**Max.**	**Standard Deviation**
Susceptibility increase on N+K due to N+2K:					
Susceptibility to N+K begins increasing at U_{N+2K}=	-79.4	-46.6	-47.7	-28.0	11.9
Susceptibility to N+K reaches max. at U_{N+2K}=	-27.0	-5.2	-6.9	-1.4	5.4
U_{N+K} threshold before increase in susceptibility	-28.2	-12.5	-13.3	-2.6	5.7
U_{N+K} threshold after increase in susceptibility	-45.2	-34.2	-33.7	-24.2	5.4
Net increase in susceptibility caused by U_{N+2K}	11.7	19.4	20.4	31.6	5.1
Susceptibility increase on N+2K due to N+K:					
Susceptibility to N+2K begins increasing at U_{N+K}=	-45.2	-34.2	-33.7	-24.2	5.4
Susceptibility to N+2K reaches max. at U_{N+K}=	-28.2	-12.5	-13.3	-2.6	5.7
U_{N+2K} threshold before increase in susceptibility	-27.0	-5.2	-6.9	-1.4	5.4
U_{N+2K} threshold after increase in susceptibility	-79.4	-46.6	-47.7	-28.0	11.9
Net increase in susceptibility caused by U_{N+K}	23.5	38.8	40.8	63.1	10.1

Models for $D = D_{MIN} + 3$ dB

Figures 10-11 through 10-17 show plots of models corresponding to a desired signal level that is 3 dB above the D_{MIN} value that was measured for each receiver. Since we made no measurement of paired-signal thresholds at D_{MIN} + 3 dB (except for those shown in Figures 10-1 and 10-2, which were not used in Figures 10-11 through 10-17), the plots are based on an assumption that IP3 / $SNR_R^{1/2}$ is the same at this low desired signal level as it was at D = -68 dBm. To help ensure the validity of this assumption, models are shown only for DTVs and channel offsets for which Table 9-3 indicates that -68 dBm was likely to be low enough to avoid AGC operation (based on the change in IP3 / $SNR_R^{1/2}$ as desired the